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"To a Nazi Bomber, It's the 'Kiss of Death'" is the title of this month's cover. Engravings were kindly loaned by the Koppers Co. of Pittsburgh


ORE
COAL
LIMESTONE

Metal Progress devoted much space, during 1942, to the supply and demand for critical metals. Among these, aluminum ranked high. It is now fitting to present an official statement concerning the present situation, which is reassuring, to say the least

Aluminum Ore and Metal Now Being Stockpiled

THE ALUMINUM SUPPLY during 1943 has been one of feast and famine. Fortunately for the war effort, the famine phase is over and aluminum production is now in the happy position of being abundantly able to supply all the requirements of the armed services, with a monthly surplus which has built up a substantial stockpile. The government is arranging to hold through Metals Reserve Co. some 250,000,000 lb. of primary metal and 75,000,000 lb. of secondary metal as insurance against any contingencies which may arise. In addition to this government stockpile, the stocks in the system may be broadly stated to be something over 750,000,000 lb. in ingot and fabricating plants, and probably a somewhat smaller amount at the aircraft plants in inventories and in process. It appears, therefore, that an amount of aluminum approaching two billion pounds exists in the United States today, exclusive of the finished metal in airplanes and equipment already delivered and in service. The situation concerning primary material (aluminum) is so comfortable that we have recently effected a curtailment of ingot capacity amounting to some 330,000,000 lb. per year.

The present condition of oversupply cannot be attributed entirely to the super efficiency of the aluminum producing plants, which were designed to take care of overall requirements of the war effort with little or no margin of safety. It is due primarily to the fact that the armed services generally and the Air Corps in particular have not consumed anything approaching the amount of aluminum which their estimates have indicated.

All of the 16 aluminum ingot plants in the country, of which nine were constructed for the government, are now in operation and a number of them are exceeding their estimated capacity. Similarly, the two large new government-owned alumina plants in Arkansas and Louisiana are operating and are now prepared to produce to capacity, using exclusively low grade, high silica, domestic bauxite.

It was largely the delay in the construction of these two alumina plants that was responsible for the famine conditions in the industry during the latter part of 1942 and early 1943 when aluminum production was barely able to keep pace with the rapidly expanding aircraft demand. At the end of 1942 there were no surplus stocks of metal in the hands of producers or fabricators. In fact, in January and February of 1943 there was insufficient metal to operate fully all the fabricating facilities. This was due primarily to an alumina shortage, but was aggravated by labor conditions on the West Coast which prevented the manning of the new reduction plants in Los

By Philip D. Wilson
Director, Aluminum-Magnesium Div.
War Production Board

An address before the Aluminum Association, New York, Jan. 19, 1944

Angeles, Spokane and Troutdale (Oregon) for some months after they were ready to operate.*

The metal shortage was attacked at that time vigorously and in various ways. Later in 1942 we requested and obtained a loan of aluminum ingot from the United Kingdom's account in Canada. This was scheduled to be repaid in February 1943, but repayment was postponed in order that the metal deficiency which still existed in the United States would not be aggravated. With the cooperation of the War Manpower Commission a successful drive was made to staff the idle reduction plants. Workers were recruited in certain surplus labor areas and settled and employed in aluminum plants in the critical areas. Housing programs were rushed to completion. Strenuous efforts were made to reduce to the minimum the "in process" or "pipeline" metal in the continuously expanding fabricating plants. In April the "controlled materials plan" was placed in operation by the War Production Board, which limited inventories, screened the raw material requirements by purchasing services or "claimant agencies", and limited allotments to the total supply. This had a definitely beneficial effect, because it immediately resulted in more realistic ordering of material. Shipments of all aluminum fabricated products in the month of March 1943, before the controlled materials plan was operating, reached a peak of 183,000,000 lb. With the new plan in effect, orders were lightened and shipments for the second quarter of 1943 averaged only 167,000,000 lb. per month. (This was effected even in spite of a large increase in production of aircraft. For example, from the time the controlled materials plan was originally announced to the end of 1943, the quarterly production of airplanes of all types increased 80%, from 14,380 to 25,950 planes per quarter.)

By April 1943 the metal shortage had been overcome and the British loan was repaid before the end of June. Beginning in late spring a then-growing metal surplus permitted an increase in allotments of lend-lease material to our Allies in excess of the original schedules. It was even found advisable to leave three pot lines idle in West Coast plants in critical labor areas in order to conserve manpower. The War Production Board was able to liberalize the "aluminum order", permitting some uses of the metal which had been restricted since 1941. Later in the year it was even found necessary to relax some of the inventory controls in order to stimulate orders by consumers.

Producers' and Fabricators' Stocks

It became possible to build up producers' and fabricators' stocks for the first time since Pearl Harbor. The government stockpile objective, which I have already mentioned (set as a producers' safety margin of 250,000,000 lb. of primary and 75,000,000 lb. of secondary metal) was instituted, and arrangements made for government purchases. Producers' stocks have been accumulating since spring and totalled some 250,000,000 lb. on December 31, 1943. In addition, the "in process pipeline" at fabricating plants was allowed to rise to about 3.6 times the monthly output at the end of the year. Consumers also increased their stocks of fabricated aluminum to approximately three months' supply.

Twenty-one new government pot lines were started during 1943 and three others were finished but left idle on the West Coast. This completed the government-owned expansion program of a total of 38 pot lines. In 1943 approximately 2,570,000,000 lb. of pig and ingot was supplied to fabricators, of which 370,000,000 lb. was used to increase "in process" material at fabricating plants. This is in addition to building up producers' stocks.

Although the metal supply was no longer critical by April 1943, problems continued to arise. During the summer months serious man-

*Mr. Wilson had this to say about his studies of ore supplies, starting in the middle of 1941: "I made as careful and detailed a reconnaissance of the domestic bauxite resources as was possible at that time and soon arrived at the conclusion that radical measures would have to be taken if the whole American continent, or even the United States, were to be made entirely independent of foreign sources of bauxite for the aluminum which would be needed in the war, which then appeared inevitable. In view of the fact that domestic bauxite was lower in grade and much less desirable for the production of alumina than South American bauxite, our first effort was directed toward planning facilities which would be able to use satisfactorily the high silica ore which could be found in the United States. We immediately initiated a large mining expansion program and concurrently started construction of additional alumina facilities so designed that they could produce metal-grade alumina from this impure domestic bauxite. A little later we added lime-soda sinter equipment to two of the existing alumina plants as well as to the new ones, designed to make possible the recovery of alumina from the red mud tailings. This red mud, which is produced in large quantities if high silica bauxite is used in the Bayer process, carries away to waste a substantial proportion of the alumina in the original ore so that the use of domestic bauxite would have been extremely wasteful if these sinter facilities had not been installed." (These problems were discussed in detail in a report by the Advisory Committee of the National Academy of Sciences, printed in *Metal Progress* for August, 1942, page 197.)

power shortages developed in the melting and the alloying rooms of the fabricating plants which threatened to curtail some of the fabricating operations. This situation was due to the high temperature and unpleasant conditions in the melting rooms and the relatively low wage rates in these operations, and resulted in the highest quit rate of any of the country's industrial activities. This difficulty was ameliorated by transferring workers from other plant activities to the melting rooms, by intensified recruiting — in many instances of high school boys — and was finally cured by the arrival of cooler weather. The starting of so many new pot lines, with the additional handicap of green crews, created a serious problem due to excessive iron in the metal coming from the new lines. Much of this newer metal had to be immobilized until it could be sweetened with purer high grade pig, so that it could be delivered into the system only a little at a time. As operating technique improved, this difficulty automatically cured itself and by the end of 1943 aluminum was being supplied at the rate of approximately 3,400,000,000 lb. per year as compared with the 1941 supply of 832,000,000 lb.

Another problem is perhaps psychological. Just because there has been a reduction in aluminum pig production, a misunderstanding has arisen concerning our need for sheet. This is unfortunate, since there is no surplus in sheet. A 60% increase in airframe weight is planned in 1944 over 1943, and this is demanding that we make every effort to meet current increases in sheet requirements, and also to prepare for greatly expanded requirements of this product expected later this year.

Supply of Domestic Ore

At the same time domestic bauxite production really hit the stratosphere! Coming largely from the state of Arkansas, its production had increased from the pre-Pearl Harbor rate of approximately 900,000 tons per year to an annual rate of 8,500,000 tons. The program as planned included 2,000,000 tons per year for Canada, on the premise that the shipping situation might not permit the importation of any South American bauxite to the North American continent. This scale of mining operations, which had been believed by many to be impossible, built a government stockpile that at the end of 1943 totalled more than two million tons. During the year, as the submarine menace began to be controlled, the War Shipping Administration and the Navy agreed, first, that we could reduce and, finally, that we could eliminate entirely the planned shipments to Canada. It became apparent that ocean shipping would be relatively freer than rail freight for these Canadian supplies, and it is now planned that all of Canada's requirements for 1944 will come by water from the Guianas. Very little encouragement, however, has been given the Aluminum and Magnesium Division that any appreciable quantity of imported bauxite will be available for the United States in 1944.

Lifting the burden of supplying Canada from Arkansas and accomplishing the stockpile objective of two million tons enabled us to curtail drastically the rate of production of Arkansas bauxite which had been built up with so much travail. The three large producers cheerfully bore the brunt of the cutback (October 1943) so that the large number of little fellows who had come into the program might continue without serious injury to complete their contracts. Plans for 1944 contemplate production geared as closely as possible to actual consumption, leaving the accumulated government stockpile intact as a reserve against contingencies.

Production of alumina in the new government plants is also being curtailed to a figure well below peak capacity. Using bauxite of a grade and quality which was considered before the war to be too low for satisfactory use in the Bayer process, these plants are operating efficiently and economically.

During 1943 the country's limited reserves of bauxite ore have not suffered the rapid depletion which was feared. Intensive exploration has put in sight more bauxite of a usable grade than has been consumed. It is now estimated that some five years' supply at the expected rate of 1944 consumption may be considered as reasonably well assured in the country. However, if the present high rate of mining should continue, it is likely that within two or three years it may be impossible to maintain this rate of production from the deeper and more scattered ore bodies that recent exploration has developed.

In anticipation of such a probable decrease in the rate at which bauxite can be mined, the Aluminum and Magnesium Division has sponsored the erection of four semi-commercial pilot plants designed to produce alumina from clay and other aluminous materials. One of these in Salt Lake City, using the Kalunite process, has been completed and is producing some alumina from alunite. The plant is encountering the many difficulties expected in a new and untried process but is making progress in solving its problems. Two alkaline process plants, one to treat clay and limestone at Harleyville, S. C., by

the Ancor process, and one to use anorthosite and limestone at Laramie, Wyo., in a process developed by the Monolith Portland Midwest Co., are in process of construction. A fourth, to employ an ammonium sulphate process developed by the Chemical Construction Corp. on Oregon clay, is being built at Salem, Ore. These proving plants each have nominal capacity of 50 or 60 tons of alumina per day. It is hoped that by early 1945 some conclusions will have been reached as to whether or not one or more of these processes may be depended upon to produce satisfactory alumina on an efficient basis and on a scale large enough to contribute to the requirements of the aluminum system. If at that time the war should appear to be a long one, and if sources of domestic and imported bauxite should for any reason not be available, such processes as may have proved successful can then be used in large commercial plants for the production of as much alumina as necessary.

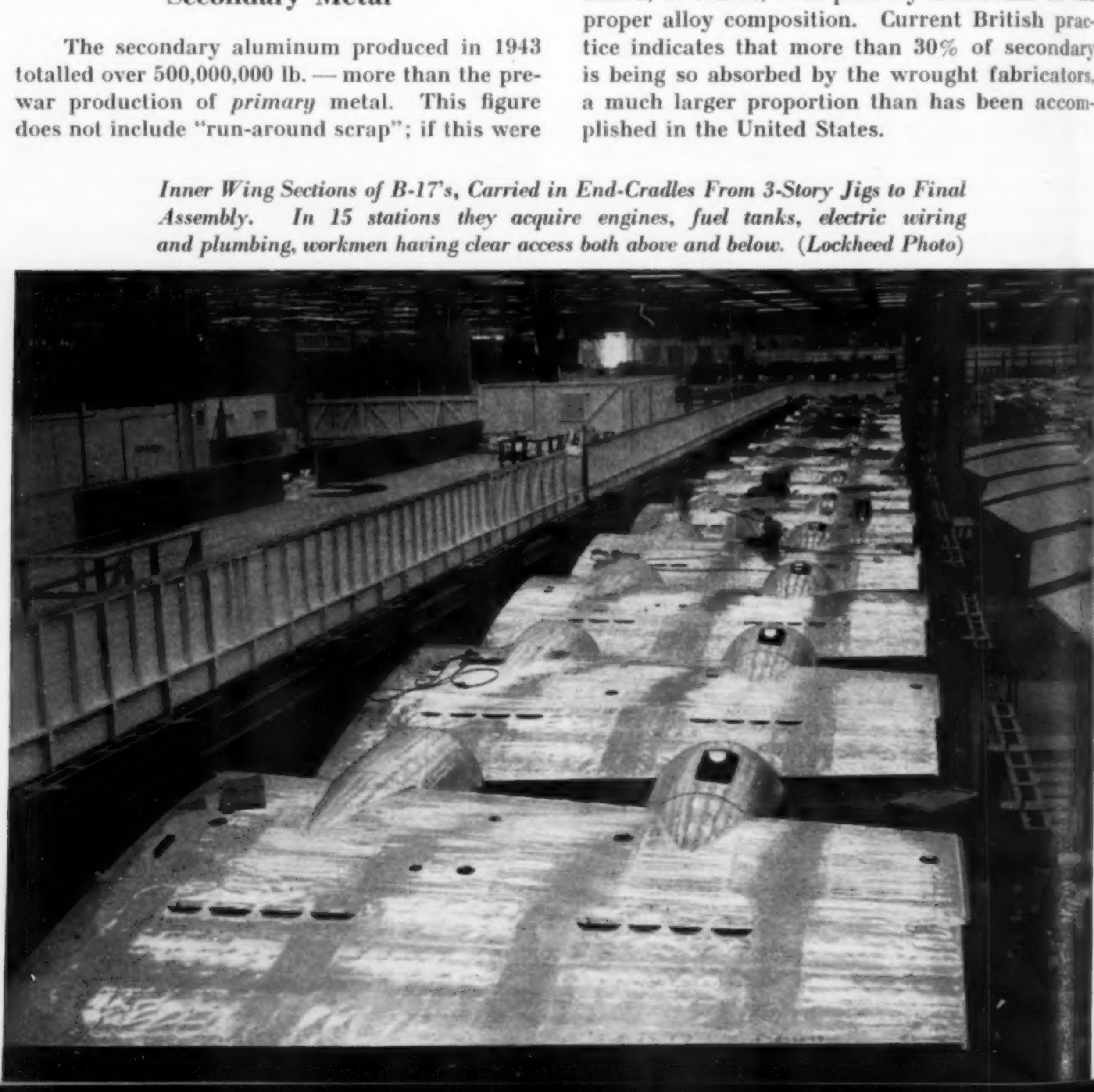
Secondary Metal

The secondary aluminum produced in 1943 totalled over 500,000,000 lb. — more than the pre-war production of *primary* metal. This figure does not include "run-around scrap"; if this were included, the volume of secondary melted from all scrap would be more than double the above figure. Aluminum scrap is remelted at some 50 widely distributed smelters and in the melting rooms of the large fabricating plants.

With the increasing aircraft program the plant scrap generated during the year increased at a high rate. Crashed aircraft has begun to swell the obsolescent scrap supply. Generation of scrap has been so rapid that it has not been possible to absorb it into the aluminum system as fast as produced, and since early 1943 a buyer's market has existed. There was no relaxation during the year in the scrap segregation operations at consumers' plants. In spite of increased scrap output and inventories, about 88% of it was satisfactorily segregated by alloy — approximately the same percentage as was being achieved toward the end of 1942.

Much attention has been given to the absorption by the wrought fabricating plants of increased amounts of secondary metal, to be mixed, of course, with primary aluminum to the proper alloy composition. Current British practice indicates that more than 30% of secondary is being so absorbed by the wrought fabricators, a much larger proportion than has been accomplished in the United States.

Inner Wing Sections of B-17's, Carried in End-Cradles From 3-Story Jigs to Final Assembly. In 15 stations they acquire engines, fuel tanks, electric wiring and plumbing, workmen having clear access both above and below. (Lockheed Photo)



Use of Surplus Metal for Essential Civilian Needs

There is every indication that all of the country's potential aluminum ingot and fabricating capacity will not be needed to fill all requirements in 1944. Certain plants and portions of plants in areas where labor is critical and where uneconomic power is being used have been and must be "cutback" to prevent stockpiles and inventories from growing to unwieldy proportions. It is possible, of course, that toward the end of 1944 war requirements may increase to a point where a larger proportion of the total capacity may be required, but that will be determined by the pattern of the war and the aircraft program.

There is naturally a growing pressure from all sides to release aluminum for civilian uses that have been almost completely eliminated during the past two years. Donald M. Nelson recently characterized the War Production Board's overall program as "dynamic balance", which might be interpreted as "drive like hell, but stay on the road". We must stay on the road! There has already been some cautious relaxation and aluminum is now permitted for a growing number of civilian items. About 200 requests for aluminum end-products, forbidden under the actual M-1-i order, are now being granted by our Division each month. For instance, use of aluminum has been permitted in the bus program, for trailers, for mess and field kits for the Army and Navy, for transmission wire, for foil to wrap bouillon cubes and yeast cakes and for a host of other things. A large allotment for landing mats for advanced airplane bases has just been approved. Requests for aluminum for such items as salt and pepper shaker tops, lipstick holders and Christmas ornaments have been denied.

Very special consideration is being given to all requests where such use would mean a substantial saving in man-hours, or of material scarcer than aluminum, an increase in production, or a better end-product. With this approach, each request is considered upon its individual merits and the fabricating problem involved. However, the War Production Board's policy is definitely opposed to a broad expansion of the use of aluminum for non-essential civilian goods at the present time. This policy is not, of course, based on any shortage of the metal but upon the conviction that over-relaxation would almost certainly jeopardize essential production for the war effort.

We have been given to understand that a very large number of men, perhaps 1,300,000, will be drafted from industry during the next six months. It is impossible to estimate the effect of this drain of manpower upon war production generally. Until the military picture becomes clearer, perhaps as the result of a successful invasion of Europe, it would be foolhardy to open the doors wide. If for any reason the projected invasion should be unsuccessful or so delayed that we will have to face a much longer war than is now anticipated, we might easily find that every available man and every available facility would be needed exclusively in war work. We must always be prepared for just such a contingency.

While there is now excess production of ingot and available unused capacity in some fabricated forms such as tubing, sheet and extrusions, there is little if any excess production or unused capacity in foil, forgings and castings. It may be anticipated that a somewhat greater volume of civilian goods will be manufactured during 1944. However, on an overall basis, there is still a very definite shortage of manpower and many war programs are falling behind their schedules.

There are still other factors involved in a broad relaxation policy which make it inadvisable at the present time. Increase in the use of aluminum for civilian goods would contribute indirectly to shortages of other raw materials, such as coal, petroleum, lumber for crating, packaging paper and transportation, all of which are now critical. Production of many civilian items from aluminum requires the use of other components, such as copper, nickel, tin and chromium, which can ill be spared. For all these reasons, general relaxation at this time would not be in the best interests of the war effort.

Although it has nothing to do directly with aluminum, you might be interested in what are considered to be the most important war production programs on the urgency list today. Apart from aircraft, which we all know represents a large segment of the expanded program for 1944, they might be listed in a very rough scale of decreasing importance; first, landing craft; second high octane gasoline; third, trucks; fourth, farm machinery; fifth, radio and radar, particularly tubes; sixth, rubber tires; seventh, forest products, such as pulp, paper, lumber and textiles; eighth, fractional horsepower motors; and last, castings, small forgings and bearings. All of these programs are considered to be of primary importance and are being given precedence over other war programs today.

An Eminent Living Metallurgist

Alfred Victor de Forest

Our Biographical Dictionary

NO ONE in the entire field of metallurgy is as rewarding to talk to as ALFRED DE FOREST. The only hitch to this statement is that you first must locate him and induce him to stay still till you get there. Keeping up with his rapid movements is a problem, although, in theory, it shouldn't be, for he is a professor. When Professor de Forest is not at M.I.T., he might be in New York at the office of the Magnaflux Corp., of which he is presiding genius, or in a Detroit airplane plant straightening out some testing problem, or in Washington telling a Congressional Committee about strains in welded ships. He might, if he had any choice, be found in the middle of Buzzard's Bay sailing the *Meta K.*, his 35-yr.-old, 28-ft. ketch, which he has been known to take out in a blizzard.

In appearance DE FOREST does not conform to the Hollywood version of a Man of Science — that is, he doesn't look like a dentist, but more like STEINMETZ, for he is a gnome-like man in his middle fifties, with a high, round forehead and a standing swirl of hair. These, together with alert brown eyes and a benign expression, make him appear to be very wise, as indeed he is.

DE FOREST's mind, like his corporal self, is constantly on the move, and if, in conversation, he is about two jumps ahead of a *confrère*, he leads gracefully. He is not content to work with the orthodox tools of his calling alone, but supplements them with empirical methods, intuition, and horse sense — a very unscientific mixture, as he admits, but often surprisingly effective. Certainly he spends as much time as possible in his laboratory or in one of his workshops, wrestling with his soul. In these retreats he is surrounded with the detritus of more than 40 years of ingenious contriving, accumulated odds and ends of electrical equipment, metal, and other stuff. He is still faithful, too, to an elderly but competent precision lathe and a venerable watchmaker's lathe, relics handed down to him by his uncles. Still in use, also, are a voltmeter and an ammeter, Model I Weston, vintage 1896. Out of this strange collection of materials comes many an otherwise unobtainable part for some new device to solve an industrial problem.....

ALFRED VICTOR DE FOREST was born on April 7, 1888, in New York City. His forebears were Walloons who left Leyden for the New World and landed in New York in 1634. He comes honestly by his curiosity and his inventiveness, for he was raised amid relatives full of the spirit of inquiry. His father, SACKWOOD DE FOREST, was an architect and an artist. With them lived an uncle, PETER KEMBLE, who worked at the du Pont powder mills on the Brandywine, and who endeared himself to little Alfred by bringing him samples of blasting powder. (Didn't seem to do him any harm.) Another uncle who lived nearby had in his house a workshop complete with wood-working tools, a lathe, photographic equipment, various electrical oddments including telegraph instruments, chemicals, batteries, and what not. Both houses contained complete photographic darkrooms. Then there was Uncle Peter's precision lathe and his watchmaker's lathe — the same ones he has today.

Another mentor of DE FOREST's youth was the proprietor of a nearby "electrician's and bell-hanger's shop", a Mr. OCKERHAUSEN, who taught him to charge batteries, file keys, repair bells, and sometimes even let him keep shop. About the time he was twelve he bought a Wheatstone Bridge, and to go with it he built — under Mr. OCKERHAUSEN's supervision — an astatic moving-magnet reflecting galvanometer with a cobweb suspension and an ungainly natural period.

With all this lore it was almost a pity to study Latin and suchlike before he could enter college, but these intervening years were spent sailing, and during this period he acquired the *Meta K.*, the boat he still sails at the drop of a barometer. The sailing bug was so strong when he entered college in 1907 that it was impossible for him to take anything but Course XIII, Naval Architecture. Because of an inordinate amount of winter sailing, and a friendship with STARLING BURGESS which got him interested in airplane building, DE FOREST took five years to graduate, and his thesis (with LUIS DE FLOREZ) was on propeller thrust, and air-speed in flight. This involved the building of recording equipment which behaved very well. Twenty years later he worked for another classmate, FRANK CALDWELL of the Hamilton Standard Propeller Co., investigating propeller stress and vibration, and today his Ruge-de Forest partnership is much involved in torque and thrust measurements and airplane stress in general.

In case any doubt still remains about DE FOREST's mania for sailing, two brief examples will suffice: In 1912 he and his father cruised in a 28-ft. boat off the coast of Alaska, with no charts, no bottom to anchor to, no wind to speak of, and nothing to eat but salmon. Father's purpose was to paint Alaskan ice, apparently much superior to ordinary brands of ice. Later in the summer of 1912, he lent his sailboat to Miss IZETTE TABER, to go from Cape Cod to Nova Scotia and back. When she returned from her voyage, during which DE FOREST's boat must have behaved *very* well, she married him, and thus has had the use of the boat ever since.

With a wife to support as well as his sailing boat, DE FOREST got a job at $12.35 a week as draughtsman with the New London Ship & Engine Co., working on submarine and diesel engines. The following year he was offered an instructorship at Princeton at $800 a year, and one at the University of California at $1,000. He chose the Princeton job (it would have cost $300 to ship the *Meta K.* to the Coast), and for the next two years taught thermo-dynamics, graphic statics, and engine lab. In the Chemistry Department he met DONALD P. SMITH ("the most gifted teacher I have ever known") who taught metallography and physical chemistry, and it was through the influence of SMITH that he became interested and finally permanently absorbed in these subjects.

In the fall of 1915 he became metallographic laboratory assistant to WILLIAM CAMPBELL at Columbia University. In this position he soon came under the eye of HENRY MARION HOWE, of glorious memory, but his teaching days in New York were very few, and he soon went to work in the Research Department of the Remington Arms Co., in Bridgeport, Conn., first as a trouble shooter, then in inspection, and finally as acting head of the department.

In 1918 he moved to the American Chain Co., also in Bridgeport. There was at that time no research laboratory, but a few years later a nice, $100,000 lab. made its appearance and DE FOREST was happy. He spent 12 busy years there, during which he made experimental developments in electric welding, machine building, and various types of inspection. One 10-year study, with FRANK FAHY as a consultant, was for a magnetic test for the quality of welded chains, a problem that is still unsolved. These weld tests did show, however, the ease with which other qualities of steel could be measured, and led DE FOREST to publish, in 1923, a fundamental method of magnetic analysis, "using the principle of the alternating-current balanced induction bridge, which deserves to be employed," he says, "more than it is today."

More papers were published on magnetic inspection and one of these, in 1928, won for him the Dudley Medal from the A.S.T.M. He also got into fatigue testing, and invented magnetic strain gages and load-measuring devices, took out a number of patents, and had "a really productive good time".

For some years prior to the depression, DE FOREST had been consulting, "on the side". When funds for research dried up, he decided to devote his entire time to this work. In 1930, then, he began a long series of testing and research assignments in many diverse fields of industry. A prize solution was one worked out for the Walworth Co., a simple test for detecting variations in the wall thickness of cast-iron pipe. DE FOREST's solution to this was the "isothermal electromagnetic method", a $50 name for a test which needs no skill and no attached instruments, takes 15 sec. to perform, and registers results visible 40 ft. away!

The most important development of these depression years, however, was a method of magnetic inspection for cracks and discontinuities which later became the basis for the activities of the Magnaflux Corp. First as a partnership with F. B. DOANE, and later as Magnaflux, the foundation was laid for a very pleasant little business.

DE FOREST's recent career as a teacher at Massachusetts Institute of Technology came about in a curious manner, and started in a disheartening conference with Harvard authorities concerning his son's undergraduate work. Later he unburdened himself to VANNEVAR BUSH, then dean of Tech., and to JEROME HUNSAKER, head of the Mechanical and Aeronautical departments, and was told in effect "to come on over and do something about it". Thus he became a professor again in 1934. "Of teaching I knew nothing, and I was familiar with little of the formal content of mechanical engineering. I regarded myself as a metallurgist using somewhat crudely the tools and ideas of physics, or even as an amateur inventor — a not particularly flattering group to belong to." The prospect, however, of teaching metallurgy to engineers, and engineering to metallurgists in a small graduate group, together with carrying on his Magnaflux business and his private consulting, was very satisfactory to him. The added association with the faculty appealed to him especially. "What a playground for a somewhat irresponsible gadgeteer and instinctive boondoggler!" he reminisces airily.

A typical cross-section of DE FOREST's prodigious daily activity can be gotten merely by sitting in his office. At intervals the talk is interrupted by phone calls; one may want him to study a circuit, or measure a strain, or recommend a magic ingredient for some special alloy. Most of these requests he has to refuse for lack of time, but he scribbles little notations on whatever scraps of paper come to hand, and at the end of the afternoon the desk is littered with these. One such piece of paper became lodged inside this writer's hat, where it was discovered later by his wife, who read it with some concern. There was a carefully drawn dagger and the cryptic message — "A 10,000-volt breakdown for you, my friend." EDWARD C. MCDOWELL, JR.

Machining and routing of aluminum aircraft parts have been done at such extraordinary speed that the whole problem of tools and machinery for cutting metals — especially steel — is again under scrutiny. Professor Boston outlines what is now being done in an organized way

New Technique in Milling

FOR A YEAR much has been heard about the high-speed milling of aluminum and magnesium, and the use of tools with negative rake for high-speed milling of steel. A number of technical sessions of the American Society of Tool Engineers and the American Society of Mechanical Engineers have been devoted to papers and discussions on these subjects (see *Metal Progress*, January 1944, page 91) and the matter is now receiving the formal attention of the War Production Board's Research and Development Committee.

In order to obtain the greatest possible production of aluminum alloy parts from milling machines, the aircraft manufacturers of the West Coast have developed and are using milling cutters designed specially for each job, and they are operated under conditions most favorable for highest production. It has not been possible, in most cases, to get specially designed machine tools, so those on hand have been speeded up principally through the use of high cycle motors. The motor power on these machines has been increased somewhat, although not in proportion to the increased speeds. Rather than reduce the feed per tooth below the normal (from 0.002 to 0.010 in.) the number of teeth in the cutter has been reduced. Inserted cutter teeth of carbon steel, high speed steel, cast tungsten-chromium-cobalt alloys, and sintered carbides are used. The bodies of these cutters are made of steel boiler plate, cast iron, meehanite, malleable iron, and alloy steel.

One of the pertinent papers given at a symposium at the last annual meeting of the A.S.M.E. was presented by W. A. Dean and R. F. Schaeffer of the Aluminum Co. of America, under the heading "Some Factors Which Will Influence the Post-War Machining of Aluminum Alloy Castings and Wrought Products". They bring out the point that because of the tremendous present capacity for the production of aluminum, aluminum will challenge the pre-war position of other metals and materials. Machine tools have, until recently, been built particularly to machine the heavy metals, so that definite modifications are needed in the post-war machine tools to take full advantage of the excellent machining properties of the light alloys. They point out further that both cast and wrought aluminum alloys machine better after heat treatment. Thus, a low temperature aging treatment of castings improves their machinability slightly, whereas a high temperature solution treatment of a casting or wrought product improves machinability, and a combination of solution and aging treatments permits the smoothest machine finish. With these treatments the alloys are in their hardest condition and tool life may be somewhat reduced. Machining characteristics of the wrought alloys are also improved by cold working.

In presenting this discussion, Mr. Dean spoke specifically of the two wrought alloys 14S-T and 24S-T. These are both of the Al-Cu-Mg-Mn family of alloys, and are given a solution heat treatment. 14S-T is aged after heat treatment while

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24S is aged at room temperature. The airplane industry has experienced little trouble in machining 24S-T. (It offers more difficult problems in extruding, while 14S-T can be extruded with relative ease.) A study of the problem of machining these alloys by the Aircraft War Production Council on the West Coast revealed the following important conclusions:

1. 14S-T warps less than 24S-T.
2. Only tungsten carbide tools are satisfactory for 14S-T, while stellite and high speed steel have been used successfully on 24S-T.
3. Below a certain peripheral speed, milling cutters gum up, but clear as the speed is increased. Cutting speeds of 8000 to 15,000 f.p.m., with feeds giving a chip not less than 0.004 in. thick, are recommended.
4. As peripheral speeds are increased, the feed should increase proportionately.
5. Emulsions of soluble oil, 1 to 15 or 1 to 30 parts water, at 100 psi. pressure are recommended as coolants.
6. 14S-T does not joggle so well as 24S-T but is satisfactory for all practical purposes.
7. In bending, the spring-back is approximately 10% higher in 14S-T than 24S-T.

Mr. Dean then proceeded to apply these conclusions to the types of machine tools necessary to take advantage of the machinability of these alloys. These factors he summarized as follows:

1. Adequate power, rigid frames, and freedom from vibration so that the equipment operates with ease at the speeds desired.
2. A range of high speeds suitable for taking advantage of the favorable machining properties.
3. More extensive use of hydraulic and electric drives.
4. Spindles well lubricated and balanced to run free from vibration at all speeds.
5. Tools of cemented carbides properly designed and sharpened to provide chip clearance at high speed.
6. Provisions for handling chips. Chips should be broken during the machining, if possible, and a conveyor should remove them.
7. Cutting compounds should be voluminous, applied under high pressure, possibly refrigerated. The liberal use of guards, preferably of transparent plastics, is indicated.
8. Efficient method of feeding work to and from the machine must be devised to speed up handling time as the machining time is reduced.
9. Special devices such as quick acting clamps to hold the work in the fixtures.
10. Rotating or reciprocating parts should be as light as possible, yet rigid.
11. Milling machines should provide peripheral cutting speeds of 5000 to 15,000 f.p.m. Speeds of 2000 to 3000 f.p.m. in turning, and up to 700 f.p.m. in drilling seem to be entirely possible.

Milling of Steel

The milling of steel has also been receiving considerable attention by West Coast aircraft manufacturers, and again new techniques have been developed. In general, face mills employing teeth of tipped sintered carbide have been found most effective when the cutters are operating at peripheral cutting speeds of from 600 to 900 f.p.m. with a feed per tooth of from 0.004 to 0.010 in. Cutter teeth for these purposes are given a double negative rake such as 10° negative axial rake, and 7° negative radial rake. Some manufacturers have found 7.5° negative axial and radial rake most effective.

It has been found that no cutting fluid at all is better than just a little when face milling steel. Fluid should be applied so that it helps to remove the chips from the work and even wash them from the fixtures. Some have tried to jet cutting fluids in large quantities through the work spindle; this proved to be very effective. Compressed air has also given favorable results.

Much has been learned from the work already done. In general, the tooth load or feed per tooth should be maintained at reasonably high values of 0.007 to 0.010 in. The speed should be high and, because of the limitations in power, the number of teeth in the cutter should be reduced, usually to 1, 2 or 4, or even 6 or 8. The advantages of high power, rigidity, and the fly-wheel action of the cutter and spindle have been found effective. A fly wheel added to the arbor and located adjacent to the cutter has been found most helpful.

Not the least of the difficulties involved in these new techniques is the need for a universal nomenclature. This is now being developed by the American Standards Association's Committee on Nomenclature.

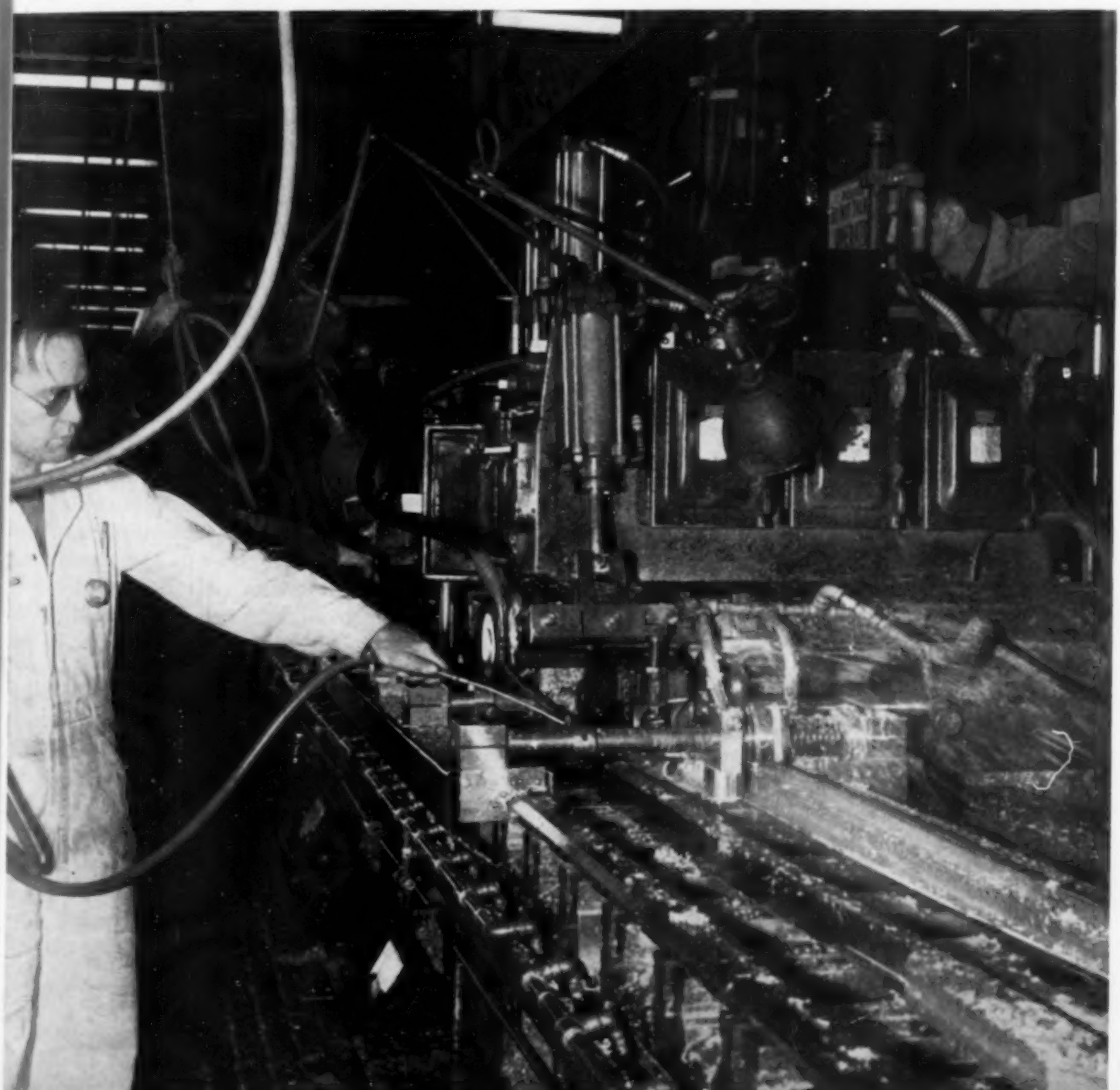
The Aircraft War Production Council, with headquarters in Los Angeles, believing these problems to be of great importance, requested financial sponsorship from the Research and

Development Committee of the War Production Board. This project has also been favorably recommended by the Manufacturing Engineering Committee of the A.S.M.E. and a contract has recently been concluded, setting up a research program at the California Institute of Technology covering both high speed milling of aluminum and negative rake milling of steel. This program is just now getting underway. A second program is being planned for the University of Michigan at Ann Arbor.

The objective of these research programs is not so much to determine what might be most desirable for the effective production of parts in the future on new special equipment, but rather to determine what might be considered good practice on equipment now available in the various shops so that all machines now in production can be operated most effectively. To disseminate this and other favorable information, the Manufacturing Engineering Committee through its secretary, Herbert B. Lewis, 40 West 40th St., New York City 18, is preparing bulletins giving illustrations and pertinent data for study by production men to aid them in operating their own equipment more effectively. Interested members of the American Society for Metals are invited to correspond with him.

These new techniques in milling are now aiding materially in the production of aircraft on which our war effort is so dependent, and their proper application in other industries can do much to compensate for shortages of machine tools and men.

Machine for Milling and Tapering Aluminum Extrusions Cuts Production Hours From 90 to 2⅓ on Main Beam and Wing Sections for One P-38. Cutters are on traveling head and traverse a bed 20 ft. long. Operator rides this carriage while two assistants handle the work and blow chips away. Carbide tipped cutters and soluble oil are used. Courtesy Lockheed Aircraft Corp. and Onsrud Machine Works



Modern Practice in Surface Hardening

Members of the panel addressing the group meeting at the October ⊕ Convention in Chicago have submitted the following transcripts of their talks. The subject of "Modern Practice in Surface Hardening" was considered under three main subdivisions.

A—Gas Carburizing

Controlled Gas Carburizing and Diffusion Cycles

By Floyd E. Harris
Furnace Engineer
Buick Motor Division
General Motors Corp.

If we are to define carburizing as the process of adding carbon to steel, then a *quantitative* analysis of that process will be concerned with factors affecting the rate of carbon addition, and with the effect of these rates on the carbon gradient from the surface inward. These factors are:

1. The steel analysis.
2. Temperature of carburization.
3. The elapsed time.
4. The composition of the gas within the carburizing chamber.

The boundary condition at the exact surface of the steel, defined for the carburizing cycle, will be so chosen that the surface carbon concentration does not vary with time. This condition postulates that at all times after the piece reaches the set temperature the gaseous medium supplies all the carbon that the steel surface can absorb; in other words, the surface concentration of carbon will represent saturated austenite throughout the cycle.

1. Under this chosen condition, the surface concentration (carbon analysis) will be a function of the steel's composition and the carburizing temperature. For a given temperature, alloying elements (especially nickel and silicon) lower the surface carbon concentration. Also the surface concentration for a given steel will vary with the carburizing temperature, being less as the temperature is lower. The effect of this variable surface carbon concentration, steel to steel and temperature to temperature, on the rate of carbon addition may be expressed in the terms of the difference between the surface concentration and the initial or base carbon content of the steel being processed, as follows: For a given steel composition, carburized at a given temperature, the *rate* of carbon addition is directly proportional to the numerical difference between the saturated concentration at the surface and the initial or base carbon concentration. The greater this spread of carbon concentration, the larger will be the amount of carbon that is added for a given time period.

2. Temperature has a two-fold effect on the rate of carbon addition. For the postulated condition of carburizing, a given temperature for a given steel determines the carbon "spread", as just stated. For this definite concentration

increase, the added carbon also varies with temperature, since temperature affects the diffusion rate, which rate increases rapidly with temperature. For example, the time required for a given carbon addition due to the diffusion rate alone is twice as great at 1600 as at 1700° F.

3. With the effect of steel analysis and temperature of the process understood, we now arrive at the time function. It has been definitely established that under the chosen condition of carburizing, the carbon added will vary directly with the square root of time elapsed after the steel has reached the carburizing temperature, and the condition of maximum carbon at the surface has been attained. From this mathematical relationship, it is readily seen that the rate of carbon addition will be inversely proportional to the square root of the elapsed time, where zero time represents the beginning of the carburizing process, when the temperature and supply-of-carbon demands are met. The significance of this rate of carbon demand is readily illustrated by the fact that the rate of carbon addition is four times as great at the end of ¼ hr. of carburizing time as is the demand at the end of 4 hr. of elapsed time. (These considerations have been expounded at length in my article entitled "Case Depth" in *Metal Progress* for August 1943.)

4. We are now ready to consider the gas phase of the process. First we will define the term "added carbon". By added carbon we signify the actual weight of carbon added to an arbitrarily chosen area; specifically the unit will be chosen as pounds of carbon for 10 sq.ft. of surface area; this represents approximately the surface area of 100 lb. of 1-in. rounds. This carbon must be derived throughout the cycle from the gas supplied for the carburizing process.

The fundamentals of gas carburizing require that extraneous reactions, outside of an adequate carbon supply, be held to a minimum. Here, two major conditions must be met: First, the total flow of gas must be great enough to maintain an adequate pressure in the working chamber. (Heated gases have a low specific gravity; at carburizing temperatures the retort gases will generally weigh less than one-quarter a like external atmosphere of equal volume. The flow, then, must be great enough to prevent contamination from the outside air.) Second, too great a supply of carbon-rich gases will deposit an excessive amount of carbon in the chamber and interfere with the carburizing process.

These conditions are met in the following manner: Pressure requirements are satisfied by the proper flow of prepared gas, very low in available carbon. To this flow is added a sufficient amount of natural gas to match the particular requirements for added carbon.

Rationale of Gas Usage

Briefly, the rationale of gas usage is as follows:

Assuming fairly dry gases, with no free oxygen content, two components only are of noteworthy importance for carburizing, namely, methane (CH_4) and carbon dioxide (CO_2). Practically 100% of the carbon in methane is available for carburization — or, if furnished in excess of requirements, for carbon depositions. Carbon dioxide, conversely, can absorb carbon at a rate equal to that released by an equivalent volume of methane, by the reaction $CO_2 + CH_4 = 2CO + 2H_2$. Thus, if methane is found in the effluent gas without carbon dioxide, it definitely indicates a carburizing condition. The presence of carbon dioxide in effluent gases, even in small percentages, indicates decarburization.

The prepared or generator gas mentioned two paragraphs above is prepared by passing moisture-free products of gas-air combustion through hot charcoal, obtaining a gas composed of approximately 20% carbon monoxide and 80% nitrogen. The carburizing properties of this gas are practically nil; at 1700° F. the available carbon of natural gas is 1200 times as much for an equal volume.

We thus arrive, by use of a suitable gas mixture, at a ready means of supplying the maximum added carbon to a given steel charge at the temperature chosen. It will be noted that throughout the carburizing period, the *steel* is the limiting factor, whereas the gas phase is merely a medium for supplying, without too great an excess, the carbon demands of the steel charge. Concise evaluations can be made of the exact carbon gradient that will be found for a given elapsed time of carburizing, as was pointed out in the article already mentioned.

Diffusion Period. For many processes this gradient may be the desired one; often, however, the surface carbon concentration represented by saturated austenite is higher than desirable. To change this rigid gradient, a diffusion period may be added to the carburizing period, all in the same cycle, by eliminating the available carbon from the gas atmosphere. All that is necessary is to stop the flow of natural gas to the retort, and the diffusion cycle proceeds with the weak charcoal gas, which has no available carbon for further carburization. Thus the carbon is allowed to diffuse inward, without the addition (carburiz-

ing) or subtraction (decarburizing) of carbon to the steel surface.

This diffusion problem is of course the reason for the rather elaborate evaluation of the factors controlling the addition of carbon to the steel surface, and of the diffusion laws which define the carbon gradient for specific conditions of operation. In this connection, it will be impossible to overestimate the significance of the work by WELLS and MEHL on the rate of diffusion of carbon in austenite.

The coined phrases "added carbon" and "carbon availability" have been used deliberately to correlate the carbon demand with the carbon supply throughout the carburizing-diffusion cycle. Simply stated, the carburizing period is one where the carbon demands of the steel are amply supplied throughout that portion of the total period when the carbon demand is the controlling factor; the diffusion period is one where *no* external carbon is supplied.

Actual operating conditions are not so simple. For the individual unit chosen, flows for proper purging, factors of retort conditioning, and control of temperature and gas conditions must all be evaluated in terms of the desired or economical heat treating cycle.

Where maximum surface carbon, or where only a few points of carbon decrease from the maximum are desired, the problem is rather simple. We have produced typical carbon gradients on S.A.E. 4820 parts weighing 360 lb. each, with 18 sq.ft. of surface area, obtaining a surface carbon of 0.50%, depth 0.120 in., in a single cycle with the complete operation at a temperature of 1700° F. Here the time to temperature was 2.5 hr., 4.5 hr. normal carburizing, 20.5 hr. diffusion; added carbon was 0.0945 lb. per 10 sq.ft. of surface. Runs such as these with low added carbon and long diffusion periods are practical, but require close control of furnace conditions.

Supposed "Graphite" in Carburized Cases

By John Welchner
Metallurgical Engineer
Steel & Tube Division
Timken Roller Bearing Co.

IN RECENT MONTHS several processers of carburized parts have become aware of, and have reported as "graphite", a surface condition which occurs as a grain boundary constituent in certain National Emergency steels. Some felt it was detrimental, or that it at least influenced the life of the finished part, because it occurs at the extreme surface. Since carburized parts are especially designed to resist wear, such grain boundary condition at the surface was viewed with suspicion, and rightfully so. The theory was advanced that the higher-than-normal silicon content of the NE9000 series steels promoted graphitization of the carbides during prolonged heating.

In the course of our investigation (described in considerable detail in *Metal Progress* for June 1943) about 20 steel types were tested with both barium and calcium energized compounds, having coke and charcoal bases. Raw natural gas, as well as prepared gases with lesser amounts of hydrocarbons and appreciable quantities of carbon monoxide, was also used as a carbonizing vehicle. Pseudo carburization was resorted to in several instances; specimens were packed in steel chips of the same analysis. Heating cycles ranged from 12 to 21 hr., followed by either a direct or a delayed quench; some samples received a double quench, which served to narrow down the theoretical possibilities. Air, oil, and water quenching, after the carburizing cycle, provided the opportunity to observe the effect of cooling rate on this grain boundary condition at the surface.

Among the 20 types tested were not only the NE9420 steel, but also a commercially "pure iron" (Armco), and steels with varying amounts of chromium, nickel, molybdenum, silicon and aluminum. These represented about all the commercial grades of carburizing steels, and included analyses containing unusual amounts of silicon and aluminum, so we could observe the specific effect of these two elements.

Certain facts were learned from this series of tests which can be summarized as follows:

1. Among the solid compounds, the barium energized material produces a much greater grain boundary attack than does the calcium energized, other things being equal. Likewise, a prepared gas, containing some 20% CO, distinctly produces this surface attack, while natural gas, with only minor amounts of CO, does not.

2. It was definitely shown that the grain boundary substances were formed during the time at carburizing temperature, and were unaffected by the method of cooling, exposure to

atmosphere during cooling, or any subsequent treatment.

3. The various steel analyses showed that no grain boundary constituent could be produced, regardless of other factors, if it contained neither silicon nor aluminum. Contrariwise, a sample of nitralloy (0.26% Si and 1.10% Al) carburized in barium energized charcoal-coke compound, contained innumerable particles far below the surface. (Usually the supposed "graphite" is found within 0.001 to 0.002 in. of the surface.)

Thus, it was concluded that the silicon and aluminum either promoted graphitization or themselves entered into a chemical reaction during the carburizing process. The first of these two possibilities is highly improbable because:

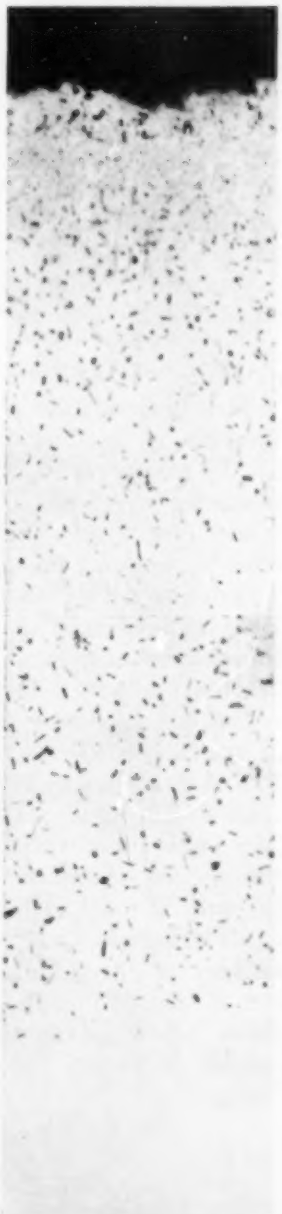
First, while silicon is known to be a graphitizer, chromium acts in the opposite manner — that is, it stabilizes the carbides. Consequently, a material with additional amounts of chromium should show less of this undesirable surface condition (if this *is* graphitization) than a steel without this strong carbide-forming element. For example, S.A.E. 4120 should be more stable than NE9420 — but actually this was not true.

Secondly, steels containing from 2½ to 5 times as much silicon as companion analyses have no greater amount of this grain boundary constituent when carburized in the same way.

And finally, reheating carburized specimens already containing this "foreign" material at the surface, in a strongly decarburizing atmosphere, does not disturb nor alter the shape or amount of the grain boundary constituent.

By the process of elimination, we are thus faced with the explanation of how silicon and aluminum can enter into a chemical reaction at the steel's surface during the carburizing process. An added clue was provided when looking at this grain boundary constituent under polarized light. Certain portions appeared to be anisotropic, like alumina, while the remainder was removed by hydrofluoric acid, which identified it as silica. That oxygen rather than carbon entered into the reaction was thus established. The most probable source of oxygen is from the CO gas. The accepted chemical reaction — $2CO + 3Fe = Fe_3C + CO_2$ — shows that while two molecules of CO are required, only one gives up its carbon to the steel; the oxygen atom thus liberated combines with the other to form CO_2 (which, in turn, reverts to CO by reaction with hot solid carbon). But when silicon and aluminum, which have such a high affinity for oxygen, are able to diffuse readily in austenite to the solid-gaseous interface (where the carburizing reaction must necessarily take place), is it not probable that some of the nascent oxygen will unite with either or both of these elements? Or, since oxygen has some solubility in hot iron, what is to prevent this element from diffusing *to* the silicon or the aluminum and thus form an oxide, deep down?

That this grain boundary constituent is not graphite has since been verified by others, as has the fact that it occurs in steels other than the high silicon NE9000 series. Its presence was discovered in S.A.E. 1015, 2320, 2512, 4620, 4820 and other common carburizing grades. Thus, the comforting fact that it is not a new "bug" to plague us is apparent. A certain sigh of relief is also excusable; if it has always been with us, it may *not* be as detrimental as thought.



Inclusions and Grain Boundary Substances in Outer 0.001 In. of S.A.E. 1015 and NE 8720 (Top and Middle). Unetched, 1000×. Bottom shows deep seated inclusions in Nitralloy G. All samples carburized in barium energized compounds

B—Hard Layers on Toolsteels

Chromium Plating, Nitriding, Carburizing of Toolsteels

By James P. Gill
Chief Metallurgist
Vanadium-Alloys Steel Co.

CHROMIUM PLATING — Industrial chromium plating or "hard" chromium plating gives longer life to many toolsteels where failure of the tool occurs by wear. It may also give easier operation on certain types of taps, reamers, milling cutters and drawing dies. Hard chromium plates can also build up worn parts of shafts, arbors, cutters or dies. Excessive deposit on the edge of the tools can most easily be corrected by a conforming anode ("thief") and by adjusting bath temperature and current density. Chromium baths have little "throwing power", so a deep recess will get no chromium unless conforming anodes are carefully adjusted.

The plate, which is applied by an electrolytic process, is generally thicker than that used for purely decorative purposes and it is applied directly to the base metal without intervening flash coating of, say, nickel. Thicknesses will range from 0.0001 to 0.040 in. Its hardness varies widely, depending upon the conditions in the plating tank, but particularly upon the thickness of the deposit; on the average it is said to have a hardness of approximately 625 Vickers Brinell.

Hard chromium plating is brittle, and it should not be used on tools which involve shock. This brittleness appears to increase as the thickness of the plating increases. Its toughness can be increased without much loss in wear resistance by heating to temperatures under 500° F., which is supposed to drive off occluded hydrogen. Chromium plate is really a solid solution of chromium and hydrogen, and undoubtedly its hardness can be attributed somewhat to the presence of hydrogen. After heating to 550° F. the hardness will begin to drop rapidly. After holding at 1900° F. the plating is fully annealed and has a Vickers Brinell hardness of only 150, and possesses little wear resistance, being soft and ductile like cast chromium. Contrary to many impressions held on the subject, there is no diffusion of chromium into the steel during plating; only at very high temperature (annealing) is this discernible.

One of the main advantages of chromium plate is its very low coefficient of friction and its ability to take a smooth finish which prevents binding and scoring of rubbing surfaces. It resists all acids but hydrochloric, although it is slowly attacked by concentrated sulphuric acid, and will retain a bright surface up to approximately 900° F.

One precaution which is necessary in using plated tools or dies is the possibility of flaking if subjected to wide temperature variations; the coefficient of expansion of the plate is less than that of steel and most other metals.

The Crowell-Collier Publishing Co. has developed an improved process in which, after plating, the tool is heated to 350° F. for about 1 hr. to remove a part of the hydrogen. Their process was described in detail in *The Iron Age* for December 10, 1942 and the company has offered to demonstrate the process to anyone who could make use of it. A few companies are regularly using the process and have claimed exceptional increase in life of high speed steel cutting tools.

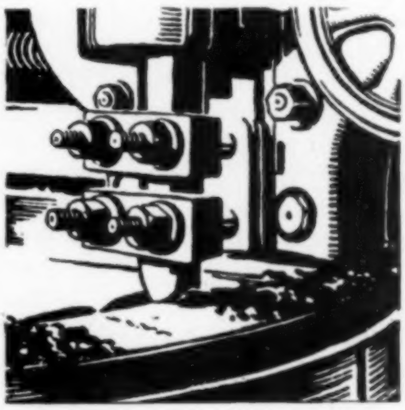
Nitriding has proved extremely useful for certain types of tools, particularly the high carbon, high chromium types, and certain die steels for hot working, such as the 5% chromium, 1% molybdenum types. These steels are usually hardened in the regular manner described for the purpose intended, and then nitrided in ammonia at about 980° F. for 10 to 60 hr. depending on the depth desired. All of the precautions relating to the nitriding process are necessary, such as preparation of the tool surface, temperature and gas control, and so on. Because of the extended time at 980° F., the body of the steel will often be softened, depending on its heat treatment and composition. Usually, however, the toolsteels that are best adapted for nitriding have a high alloy content and will therefore soften at a much slower rate than the regular types of nitriding steels; thus the hardened nitrided case has a backing of comparatively hard material so that it will not crush or "sink" when subjected to comparatively high pressures.

High speed steels are seldom nitrided, because ammonia apparently builds up too high a concentration of nitrides at the surface, and causes extreme brittleness. A few types of tools for the cutting of cork and ceramics have been nitrided with success, but only rarely have nitrided high speed steel tools been satisfactory for metal cutting. On the other hand, nitriding

of high speed steel by immersion in molten cyanides has been widely used for many types of tools such as taps, chasers, reamers, form tools, and broaches.

High speed steels that are to be nitrided by immersion are hardened, tempered and ground in the regular manner, and then immersed in a molten bath of potassium and sodium cyanide. A bath of 53% NaCN and 47% KCN is a eutectic mixture melting at 936° F. when freshly prepared from chemically pure components. In the interests of economy commercial baths are usually made of 60% NaCN and 40% KCN, and additions of NaCN alone or mixtures of 70:30 NaCN and KCN maintain the bath strength. The melting point will be lowered on use by reason of surface oxidation and internal reactions, and when completely "aged" the bath will be partially molten at 775° F. and entirely molten at 925. Oxidation of the bath and the internal reactions are responsible for the liberation of free nitrogen which is supplied to the steel; thus, the amount of free nitrogen is a function of the cyanate (CNO) content.

A typical bath, freshly prepared from commercial salts, will have the following composition based on the content of the major negative radicals occurring: Cyanogen (CN) 45%, cyanate (CNO) 1.1%, and carbonate (CO_3) 1.9%. If pure salts are used the initial cyanogen content will be 47.8%. A properly aged bath will contain approximately 25% cyanogen (CN) and approximately 12% cyanate (CNO), with from 10 to 15% carbonate (CO_3). The carbonate is an end product of the decomposition of the bath and should be removed periodically by lowering the bath temperature to 850 or 900° F., at which temperature "salting out" occurs; the carbonate settles to the bottom and can be removed with a perforated spoon.



The "aging" process can be carried out by holding a new bath at 1000 to 1100° F. for about 12 hr. Increasing the temperature of aging favors the formation of cyanate up to a certain point; its decomposition to carbonate becomes predominant at higher temperatures, however. A bath originally composed of 70% NaCN and 30% KCN will age in 12 hr. at 1050° F. to a cyanate content of approximately 9%.

The bath may become contaminated with nickel when nickel-chromium-iron alloy pots (35% nickel, 15% chromium) and pure nickel thermocouple tubes are used. The nickel in the bath will then plate out on the tool being nitrided to a thickness of about 0.0001 in. This appears as a white discontinuous rim under the microscope and may easily be mistaken for carbide. At excessively long nitriding times this plate may cause a crumbly layer 0.0002 in. thick. This nickel plate will prevent nitralloy from absorbing nitrogen from dissociated ammonia, and while it does not prevent nitriding of high speed steel in cyanide baths it considerably retards the penetration. A surface free from nickel will have a steely metallic luster after cleaning and will resist attack by 25% nitric acid; surfaces contaminated with nickel have a characteristic dull gray appearance and are readily attacked after 10 to 20 min. in this acid.

Absorption of nitrogen by hardened and tempered high speed steel follows the same general pattern of the absorption of carbon in carburizing. The nitrogen content will be highest at the surface and decreases rapidly to a value equal to that in the steel core. Although not generally recognized, the nitrogen pick-up of an annealed high speed steel is essentially the same as that of the hardened and tempered steel.

Tools which are nitrided in fresh baths and those nitrided for short times in aged baths show exceptionally steep nitrogen and hardness gradients. It is this condition that is believed responsible for brittle cases. To avoid trouble longer immersion periods, higher temperatures or the use of a thoroughly aged bath is recommended. The cyanate content should exceed 6% in order to avoid brittle cases after relatively short immersion times. A time of 20 to 30 min. at 1000 to 1050° F. usually proves most satisfactory.

Carburization of toolsteels can probably be of much greater use and adaptation than ordinarily supposed. It will impart high resistance to wear and in most instances does not materially increase the brittleness of the tool. It is not well adapted for cutting tools, but proves very satisfactory for many types of tools subjected to wear or abrasion. It also works very well for many types of bending dies, blanking dies and for many other tools of a similar nature.

Tools which are pack hardened in order to obtain a clean surface are often carburized in the process, even though the packing compound is of a nature to minimize such action. This is

particularly true when the hardening temperature is above 1750° F. Usually high carbon, high chromium steels and high speed steels and many types of hot work die steels will show a definite carbon pick-up after pack hardening. This is probably highly advantageous to the first two types, but likely to prove detrimental to die steels for hot work.

Low alloy toolsteels which are heat treated from temperatures under 1700° F. usually require a carburizing compound if the carburized layer is deep enough to be of value. Typical would be a tungsten chisel steel, which usually hardens to about C-57 or 58 Rockwell on oil quenching but which, when carburized, can have a surface hardness as high as C-66 or 67.

Carburization of high speed steel is never recommended for cutting tools, for the increased carbon content embrittles the edges and may result in early chipping. For many types of blanking dies and wearing parts, carburized high speed steel is of great advantage. It is usually performed by packing the steel in charcoal and heating to about 1900 to 2000° F. A holding time of from 20 to 30 min. is sufficient, since if the surface carbon should become too high the melting point of iron-carbon alloy at the surface may be reached. In such a case the tool may come out badly pitted or blistered. The tungsten types of high speed steel absorb carbon at a slower rate than the molybdenum types, and since the latter steels have an initially lower hardening temperature the corresponding carburizing temperature should also be lower. Air cooling from the carburizing temperature is usually preferable to oil quenching.

C—Modern Practice in Differential Hardening

Utility of the Hardenability Test on Steels for Carburizing

By O. W. McMullan
Metallurgist
Youngstown Sheet & Tube Co.

THE DISTINCT differences between the character and function of the case and core make it necessary to consider them separately in connection with hardenability tests. There are any number of hardenability tests suitable for specific applications, but since the Jominy end-quench test covers a broad field and has become more generally accepted, and even standardized, that test will be chiefly referred to in this discussion.

The first publication, six years ago, by JOMINY and BOEGEHOLD on their end-quench method referred to carburizing steels; the specimens were carburized and the hardness tests made on the case at different depths from the surface. Only a few tests were made on the core. More recently the situation has been reversed and the test confined almost entirely to the core. I am of the opinion that this change has been made many times without good reason. Since the core is protected by the case the latter receives the wear and highest stresses, and should receive primary consideration. Others are of the same opinion, as witnessed by ALMEN's statement in February 1943 *Metal Progress* that in most gears "the core serves mainly as a stuffing for the case". The properties of the case are *always* of importance; in many applications the properties of the core may also be of importance — in any event they cannot be neglected entirely.

First then, let us consider the relationships between the case and core which determine their relative importance. For certain types of simple loading, such as straight tension, compression and simple shear, stresses are distributed more or less uniformly throughout the section and the properties of the core and case are of equal importance. Most types of service loading, however, involve bending or torsion stresses, where maximum stress is in the case (near the surface) and the importance of the core depends on case depth and design of part.

The diagram illustrates the following:

1. Theoretical stress lines (*O-D*, *O-*K_1 and *O-*B_3) from bending loads which produce certain surface fiber stresses.

2. Actual load carrying capacity of case and core for 2512 as determined by hardness and bend tests (lines A-A_1-B_1-B_3, etc.).

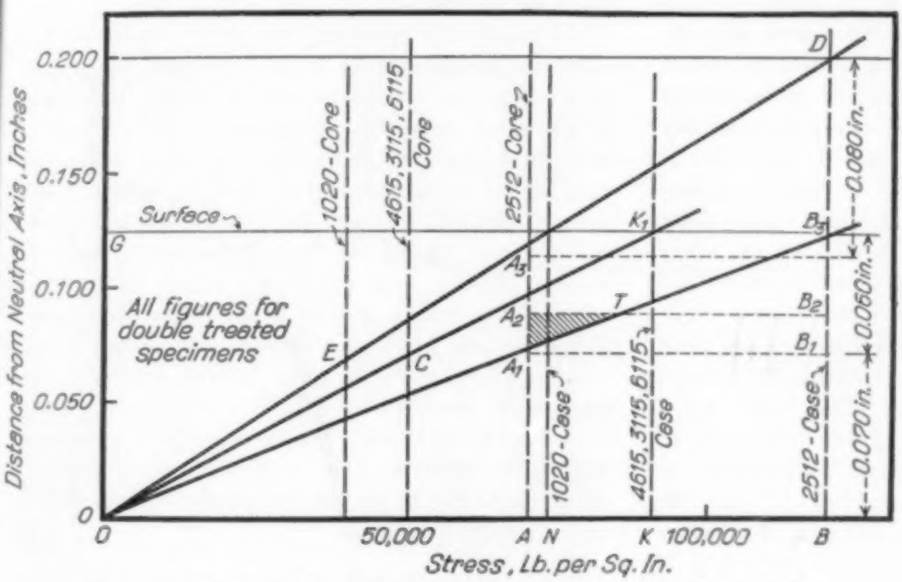
3. Where the load carrying capacity line is to left of the line showing actual stress (as at A_2 in the line A-A_2-B_2-B_3) failure will take place at that point, A_2, whether it is in case or in core.

4. Point of failure in border-line

parts depends on the relative thickness of case and core. The slopes of the stress lines O-K_1 and O-B_3 show that for average case depths the case is all-important in small parts, while with larger parts the properties of the core must be considered.

The Jominy test, considered as a method of predicting the properties of a steel after quenching, is not as suitable for obtaining core hardenability of ordinary carburizing steels as it is for the higher carbon, deeper hardening steels. With the standard 1-in. solid cylinder test bar, steels of low hardenability have a narrow hardness spread, and shallow hardening steels have a short hardened zone, thus causing the method to lack sensitivity. The L-type specimen, so-called, overcomes some of these objections, but is a more difficult specimen to make, and departs from the fundamental idea of quenching by conducting heat through the steel in a direction normal to a plane surface. Other special hardenability tests, such as the hardness at the center of a quenched 1-in. cube, are designed to fit specific applications rather than for acquiring general information. For the latter purpose the standard Jominy test appears to be best, and has the advantage of tying in with data being collected by S.A.E. and A.I.S.I. committees.

Definite recommendations for hardenability ranges cannot be made without knowledge of the size, design and stresses applied to the particular parts. In general, it can be said that the best combination of mechanical properties in any steel is produced by an ideal distribution of micro-constituents obtained by quenching to produce 100% martensite without separation of other constituents in the grain boundaries, and then tempering to remove internal stresses and produce the required toughness. Structures containing 50% martensite and similar mixtures are undesirable; they promote brittleness. Ideal structures of full martensite can be obtained only in small sections of the low carbon steels, in view of the low hardness levels desired in the core and the oil quenching procedures. Larger sections would necessitate steels of low carbon and high alloy content — impossible under present alloy shortages, economically unjustified in peace times, and also unnecessary for satisfactory performance in the majority of applications. As shown in the diagram, high core strength may have little significance in service. In most instances where it does, if an ideal structure were produced in the more highly stressed zones of the core lying immediately below the case, little concern would need to be felt over the interior of large sections. Determination of



Theoretical Stress Distribution in Case and Core (After Woodvine)

Stress, plotted against distance from neutral axis, represents the stress conditions in the tensile half of bend test specimens, 0.400 and 0.250 in. square. Assuming a case depth of 0.060 in., fatigue strength in core of 2512 of 70,000 psi., and case strength of 120,000 psi., the load carrying capacities would be represented by lines A-A_1-B_1-B_3. Any higher stress — that is, to the right of these curves — would cause failure. Now consider a load applied to the ¼-in. specimen that will produce the safe stress of 90,000 psi. in the outside fibers of the case (point K_1). Theoretical stresses at other locations will then lie along lines O-K_1; obviously the 2512 part carburized 0.060 in. will be amply safe. If, however, the part were loaded to the fatigue limit of the case, 120,000 psi., the stress line O-B_3 would be dangerously close to the fatigue limit of the core (point A_1). A part with a slightly shallow case and having a stress line A-A_2-B_2-B_3 would fail in the core just below the case at A_2.

Core failures may be prevented in two ways: *(a)* By increasing case depth or *(b)* by increased core hardenability and strength. From the slope of the stress lines O-D and O-B_3, it is obviously more feasible to work with core strength in large sections, and with case depth in small sections. From a practical point of view, these relationships are altered by internal stresses; nevertheless core properties may be of importance, particularly if the part is large or the case thin, whereupon hardenability tests are needed for both the case and core.

the cooling rates in the critically stressed sections would form the basis for establishing the required Jominy hardenability limits.

There has been a tendency to include in specifications for carburizing steels Jominy hardenability requirements with upper and lower limits in the form of a band on the chart. While such a "band" specification may represent an ideal for which to strive, the art of steel making has not reached a stage of development which will permit working to as narrow a band as some request without too great a loss in rejected heats. Likewise it is extremely doubtful if engineering knowledge of stresses and conditions encountered in service has developed to a point where it can be proved that the chosen band actually includes *all* of the most desirable range. A more reasonable starting point would appear to be the establishment of a minimum limit.

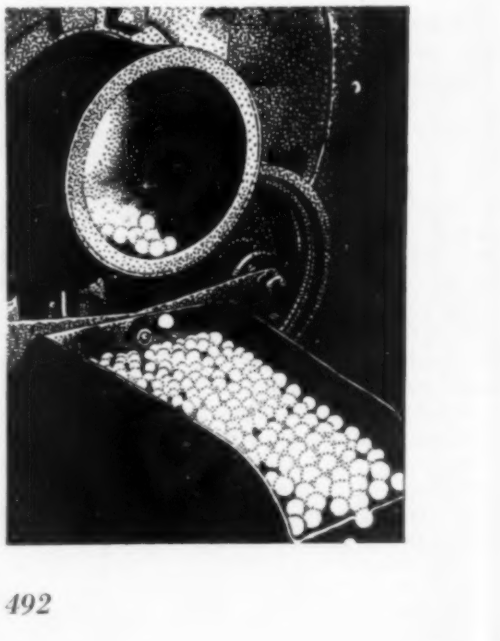
Another point to be kept in mind is that the critical portion of a Jominy curve may be far shorter than its total length and to establish limits outside of this zone imposes unnecessary restrictions. For example, a complete Jominy curve might set a minimum limit on the core at 2½ in. which would serve only to require higher alloy content and perhaps at the same time have adverse influences on machinability or other properties. Such unnecessary restrictions do not increase production or conserve materials.

The importance of the case has already been emphasized; consequently its hardenability should not be overlooked. Perhaps there may be a tendency to feel that sufficient hardenability in the case is not difficult to obtain, particularly in alloy steels. This is not always true. On the other hand there can be what, for lack of a better term, might be called too much hardenability — that is to say, the retention of too much austenite. One of the most prolific sources of hardenability troubles in mass production is found in casehardening carbon steels. While other factors aside from steel itself, such as adhering scale or steam pockets, play an important part, low hardenability heats are most adversely affected.

Parts too large for steels with the lower alloy content are sometimes encountered. One instance in my own experience occurred years ago when we first started direct quenching. A large ring gear of S.A.E. 4620 steel would not attain sufficient hardness when reheated and quenched from 1525°, but was O.K. as direct quenched. Willard Waisner of Mechanics Universal Joint has recently reported a similar circumstance with large spiders made from NE9420 steel. These experiences cast no reflections on the types of steel, but merely that they were applied in parts too large for the hardenability of the case.

Arbitrary tests, such as carburizing a certain size round and quenching at a definite temperature, appear in some specifications. These are suitable for specific applications, but do not lend themselves to universal application and correlation of results obtainable from standard Jominy tests. Steels subject to the formation of austenite may require tests after grinding as well as on the original surface. Quenching temperatures should correspond to those used in production, because of marked influence of quenching temperature on retention of austenite. A suitable hardenability limit can then be established in the usual manner. It should be obvious, also, that by making the proper selection of results the Jominy test can be applied to other special casehardening processes such as cyaniding, or dry cyaniding where nitrogen is partially responsible for the eventual hardness.

Frequently mention has been made of the fact that hardenability tests determine one property only, but also serve as a rough indication of the other physical properties. Ability to predict final physical properties in a casehardened part from a hardenability test is much more limited than in through hardening steels. Internal stresses set up by the differences in hardenability of case and core may much more than offset the strength gained from higher hardness. For example, bend and impact tests show much lower values in higher alloy steels direct quenched, than when double treated to produce lower core hardness. Limitations of the hardenability test must be kept in mind in such applications, but the scope of its usefulness is broad when properly applied.



Differential Hardening With High Frequency Current

By F. F. Vaughn
Asst. Chief Metallurgist
Caterpillar Tractor Co.

INDUCED high frequency current provides an ideal method of heating for differential or surface hardening. During recent years there has been rapid development in the design and use of equipment for this purpose. In fact, equipment is available today that might rightly be classed as a series of machine tools for differential or localized hardening — machines which reduce the process of such heat treatment to machine-tool precision.

Principles of the process may be briefly described: If a steel part, such as a shaft or axle, is placed within a wound coil or inductor which carries sufficient alternating current, it becomes heated at that portion within the magnetic field of its inductor. With enough power supplied, the heat developed will be sufficient to bring the localized surface zone up to the critical temperature in a few seconds.

In practice, the desired surface should be heated as rapidly as possible, followed by instant quenching to produce the desired hardness.

It is characteristic of high frequency alternating current to concentrate its flow at the surface of a conductor (in this case the part to be hardened) and the higher the frequency the greater this tendency. This characteristic is known as "skin-effect" and must be considered in connection with the depth of hardening desired. For differential hardening to very shallow depths, in the order of 0.010 in. or less, the use of 1 to 5 megacycle frequency generated from a tube converter, with sufficient power to confine heating to that depth, would be logical. For somewhat greater hardened depths, say 0.010 to 0.030 in., the same type equipment producing 200 to 500 kilocycle frequency current would be preferred. For hardened depths of 0.025 to 0.040 in., similar equipment producing 50 to 200 kilocycles would be preferable. Even greater hardened depths, say 0.020 to 0.040 in., would indicate the same type equipment but with 150 to 300 kilocycles. For still greater hardened depths, motor-generator sets with frequencies of 1000 to 9600 cycles may be preferred, particularly if high power input is required.

Since most of the energy is changed to heat near the surface regions, the ideal procedure requires sufficient power to confine the heating to just that depth to be hardened. To minimize heat travel by conduction, an extremely short heating time is moreover obviously essential.

Induction heating takes the affected zone to a high temperature, compared to conventional heat treating temperatures, so that diffusion within the heated region is very rapid, yet time at temperature must be so short that excessive grain coarsening, ordinarily expected to accompany such temperatures, does not occur. In fact, rapid heating results in a better metallurgical structure of the hardened area and a better bond between the hardened area and core than follows more leisurely procedures. This method also produces extremely fine martensite in the hardened area, since the long needles frequently associated with this structure do not have time to form.

Power input and time must therefore be under "split second" control to insure complete solution on the one hand and prevent overheating and resultant disaster to the piece being hardened on the other.

Modern equipment now available controls these factors to this accuracy, and when such controls are once established, they are capable of automatic repetition with extreme regularity. For example, we have surface hardened, differentially or completely, millions of parts in which the specified depth of hardness penetration must be maintained within $\pm$ 10%.

The uniformity and speed of heating and quenching minimize, or in most cases eliminate, the following costly and time consuming operations usually associated with conventional methods of heat treatment: Protection against carburizing; decarburization; cleaning; distortion; straightening and differential tempering.

The method is of special importance today because it can be used to harden carbon steel parts with extreme rapidity, and affords a means of conserving critical alloys.

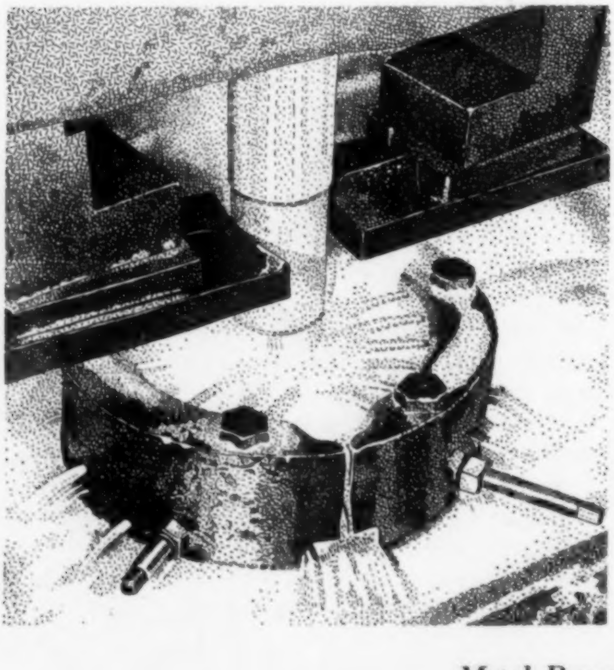
There seems to have been a somewhat general misconception that it is essential to have chromium alloyed in the steel in order to harden parts satisfactorily by high frequency induction. As a matter of fact, adequate surface hardness can be obtained *without* the presence of alloying elements. Maximum surface hardness is a function of carbon content of the steel and, consistent with proper metallographic structure, increases from Rockwell C-61 for 0.35% carbon steel to a maximum of C-68 for 0.70% carbon steel.

Many millions of machine parts requiring only localized hardened areas are today made of oil hardening types of alloy steel to minimize distortion or overcome mass effect when heated bodily in a furnace and subsequently quenched. For many of these applications, simple carbon steel, differentially hardened with high frequency current, can be substituted for the conventionally hardened alloy steel, and the parts produced will be free from excessive distortion without interference from mass effect.

For certain highly stressed applications where a considerable degree of overall toughness and strength is required, suitable carbon steel may be subjected to a preliminary furnace treatment in the "rough", or in coarse machined state, prior to differential hardening the highly finished part with high frequency current. For many applications, however, this preliminary heat treatment will not be required.

We have successfully used high frequency current for the differential surface hardening of millions of production parts of many types, such as crankshafts, track link pins, axle shafts, pump shafts and cylinder liners.★ A major requirement of these parts is high surface hardness to a specified depth for prolonging their service life. Such applications require that these parts be produced without over-heating and resultant brittleness. Many of these parts were formerly carburized and hardened, others were made of alloy steel directly hardened. In actual service, performance of the parts has been satisfactory.

★See, for example, "Casehardening Large Gears With High Frequency Current", by Glen C. Riegel, *Metal Progress* for July 1943, page 78.



Putting Flame Hardening to Work

By Gordon T. Williams
Sometime Metallurgist
Deere & Co.

THE TERM "flame hardening" is used to cover a type of special heat treating procedure wherein a limited portion (a small area or a surface layer) of a piece is heated by a concentrated flame of burning gas to above the critical range and then cooled fast enough to produce a hardening effect. If the temperature is not high enough, or the cooling not fast enough, and a softening by tempering or annealing is produced, the process is called "flame heating" or "flame annealing". Let us now consider the possible application, limitation, equipment, and costs of such treatments, together with a few examples of jobs which have been done.

Applications for flame hardening take advantage of the selective or localized effect, and thereby overcome the disadvantage of high unit costs. In general, flame hardening is used *(a)* where hardening is required only on limited parts of the surface of a piece, *(b)* where conventional treatment would produce excessive distortion, *(c)* where hardening the whole piece would result in dangerous brittleness. Typical uses in various manufacturing industries include:

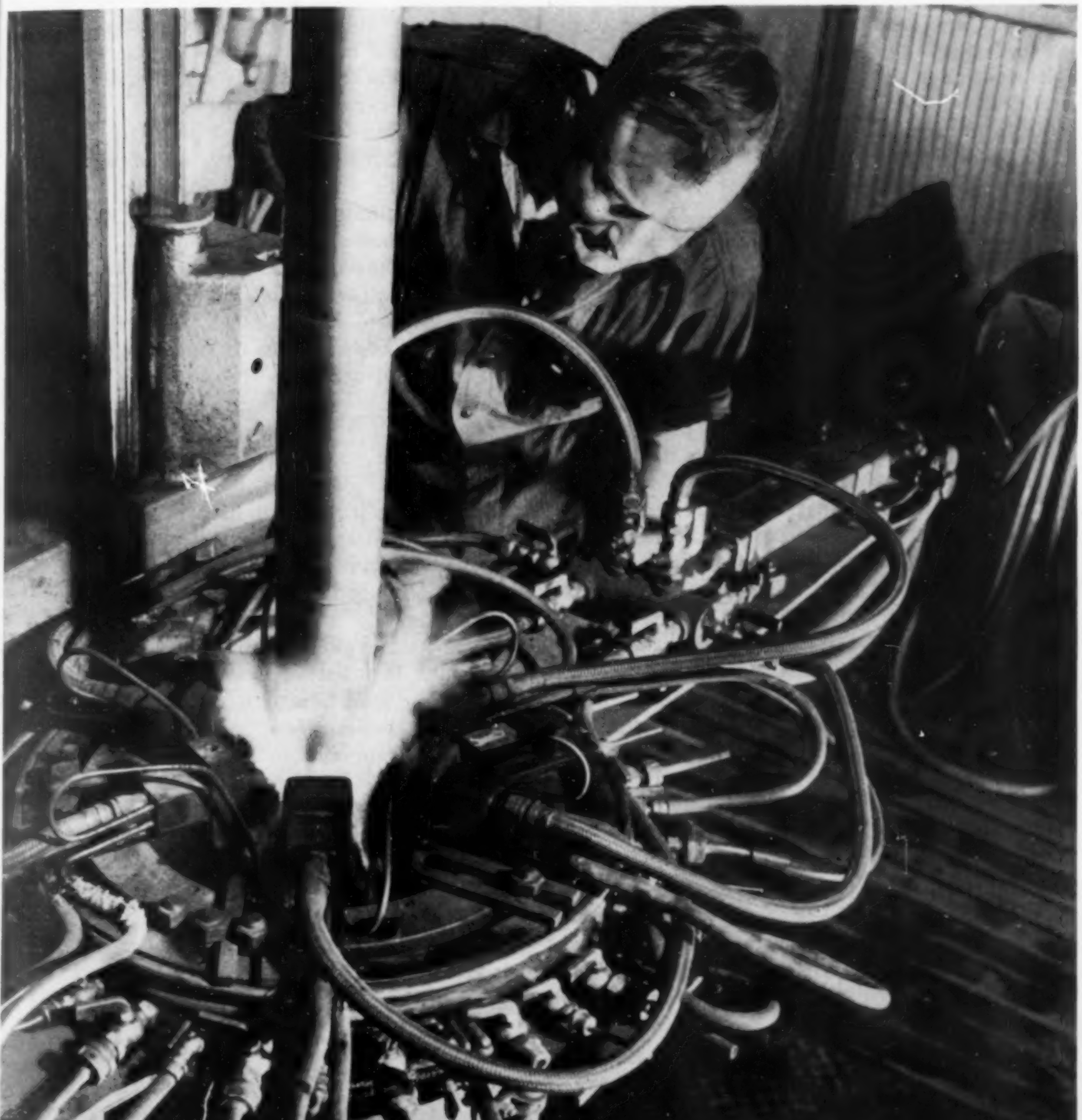
- Lathe ways — wearing surface hardened.
- Large gears and sprockets — hardened on tooth faces.
- Wheels — rim hardened.
- Wheel hubs — bore hardened.
- Tank track treads — wearing faces hardened.
- Camshafts — cam faces and oil pump gear hardened.
- Intake valves — tips of stems hardened.
- Large or long shafts — short bearing areas hardened.
- Levers and pawls — contact pads hardened.

Hardenable Materials — In general, any steel which can be hardened by ordinary heating and water quenching can be flame hardened. Plain carbon steel, containing 0.35 to 0.50% carbon, is usually selected. Moderate alloy steels such as S.A.E. 4140 chromium-molybdenum or 1340 manganese steel may be used if sections are massive,

but locally heated alloy steels always present the hazard of cracking when quenched. Pearlitic malleable iron is especially adapted to flame hardening for it can readily be hardened in spots to provide excellent wear resistance, but if quenched all over and not well drawn back its brittleness would be excessive. Common gray iron can be flame hardened to a limited degree; the higher strength gray irons containing high combined carbon are quite hardenable.

Methods — There are two types of useful flame, that is, oxy-acetylene and gas-air (natural or artificial gas). The oxy-acetylene flame is several times as costly a source of heat as a gas-air flame, as far as the gases are concerned, but provides much more concentrated heating, so that smaller zones or areas of an object can be brought quickly to heat, thus restricting the hardened portion; furthermore heating is rapid enough that burners may include a bank of water jets which follow the flame closely and immediately quench the heated zone as the flame moves over the work. (This is known as the progressive method of hardening.) An air blast may be used for quenching if water is too drastic, but flammable oil of course cannot be used. In many applications of the oxy-acetylene flame, and almost always when gas-air flame is used, the area to be hardened is heated by the burner, then the quench is applied to the whole region by

Shaft Hardening Machine, Made From an Up-Ended Lathe. Burners are attached to the tool carriage; as the shaft is rotated the flames progress upward, followed by a ring quench. (Linde Air Products Co.)



spray jets or by immersion; if the piece is immersed, oil can be the quenching medium. Bearing areas on shafts, cams on camshafts, and various other circular pieces are best hardened by spinning the piece with a burner covering the whole width, then quenching the heated area or the entire piece. Tooth faces on narrow gears are usually hardened by the progressive method, the gears being stacked or bundled together and the burner, with quench jets following, moved across the group on the pitch line. The progressive method is also useful for long flat surfaces such as lathe ways. Tank treads may be hardened either way, usually by full-area heating.

Actual quenching is not always required; frequently the surrounding cold mass of metal, if large and near, cools the heated zone fast enough by conducting the heat away rapidly.

Oxy-acetylene heating seems to have its best application where sharp, localized heating is needed, while gas-air is most useful when more gradual heating with some spreading may be tolerated. For this reason gas-air is more often useful than oxy-acetylene for "flame annealing" since local overheating is less likely.

Equipment

Oxy-acetylene — Gas supply system to be used depends on consumption, as with welding. Tanks or cylinders, manifolded if necessary, suffice for moderate flows, while acetylene generators and liquid oxygen containers are economical for big jobs. Burners are of special type (unless just a spot of heat is required, when a welding tip is useful) and can be purchased or made in the tool-room. A series of fine jets — about No. 60 drill size on ⅛-in. centers or the equivalent — in one or more banks, will give good uniformity. The head or burner block should be cooled by water flowing through internal passages, else it will burn up. Quench jets, if used, are usually about No. 72 drill size. Mixing torches are of the same type as used for welding, but the larger sizes are usually required. Leading manufacturers of oxy-acetylene equipment offer engineering service, have lines of standard torches, and will design and build special burners.

Gas-Air — Best efficiency demands accurate proportioning of gas and air with good pressure control; thorough premixing is also advantageous if maximum flame temperature and uniformity are required. For this reason many installations use gas and air premixed by "carburetors", while other firms making gas equipment offer standard burners which are useful for many jobs. The slower rate of heating by gas-air burners usually prohibits use of the progressive method. Several firms offer specially developed equipment for certain jobs; often these take the form of a chain conveyor carrying a procession of parts past flames or radiant cups, or through a slot furnace, gas fired.

Costs

Fuel — A rough rule for flame hardening by oxy-acetylene is that 1 sq.in. heated and hardened ⅛ in. deep will require ¼ cu.ft. of each gas, or will cost roughly ½ to ¾¢ if cylinder gas is used. Gas-air mixtures will cost $\frac{1}{10}$ to ⅕ of these figures. A rate of 4 to 6 in. per min. is average for progressive hardening by oxy-acetylene.

Equipment, including burner heads, torches, regulators, and valves, will run upward from $100 for a simple job. Much of this may be already available in the welding shop's tool bins. If mechanism is needed to rotate the work or to move it or the burners, this will add substantially to the cost, even if adapted from an old machine tool. Equipment for gas-air hardening will run from just a few dollars for a simple burner and mixer of the common heating type, to several hundred dollars for a complicated or patented mixer and burners, plus mechanism.

Flame hardening is not cheap. It may however turn out to be the cheapest way of accomplishing a job, even in mass production. Equipment cost is lower than for induction hardening but operating costs (especially with oxy-acetylene) are usually much higher.

Limitations

There is the usual hazard associated with use of oxygen and acetylene — which, one might say, is no hazard at all *if* proper and well known precautions are taken (a big *if*, these days). On the other hand, when a premixer is used for gas and air, an explosive mixture must be handled, and such installations should be carefully engineered and maintained. Reliability of flame hardening depends entirely on the control and care used in the operation; the personal equation is important. There is no direct control of temperature, constancy of operation being the only way of getting uniformity of results. The oxy-acetylene flame is very prone to cut or burn the surface if moved too slowly or held too long in one spot, or on entering or leaving the work at an edge. Cracking of the work during the quench is also a hazard, especially if the surface has been overheated.

Continuous Casting

INTEREST in the Symposium on Continuous Casting held by the American Institute of Mining and Metallurgical Engineers at its annual meeting in New York late in February can be best described by the single notation that proceedings commenced on the appointed hour of 9:00 A.M., with an audience of 200, most of whom gave the impression that they insisted on grand stand seats. Within short order another hundred took up positions in the rear as the chairman, Carl E. Swartz, opened the first notable public gathering for the discussion of an art now 100 years old, but still in its infancy as a commercial practice.

Appropriately, Tom W. Lippert, managing editor of *The Iron Age*, the first speaker, cut through the very formidable maze of patent literature that has been accumulating at an ever accelerating rate, to present a clear picture of the history and growth of the process in general. It can hardly be said that the pattern is one of orderly progression; rather, the basic difficulties common to all of the many techniques now in vogue are greatly accentuated, first one, and then another, by the variety of metals under consideration, and their associated physical properties and the economic factors. Thus, a wide latitude is apparent in the various processes in current operation, resulting in rather startling differences.

Almost invariably the first question that comes to mind with regard to continuous casting is "How fast can you run?" This review brought out the fact that present speeds range from about 6 in. per min. of billet length to 10 to 15 ft. per min. Perhaps it might be more pertinent to ask "How long can you run and at what cost?", for indeed two successful commercial processes (A.S.&R. and Alcoa) have been in continuous operation for several years at speeds of 10 in. per min. or less, respectively casting copper and aluminum alloy billets, presumably at competitive cost with other methods employed in those industries. (See "Critical Points" in *Metal Progress*, January 1944, page 108.)

While the present status with regard to the various processes is hardly a race between the hare and the tortoise, due to the tremendous differences in the particular factors each is trying to overcome, one cannot help but be impressed that mechanical difficulties have had the upper hand for years. Mr. Lippert's appreciation of the art, serving as it does to eliminate the irrelevant and extraneous from the overall picture, is well worth reading, and may be found in its entirety in *The Iron Age* for February 24, 1944.

Further discussion of the physical and mechanical requirements was ably supplied by Norman P. Goss, consulting engineer of Cleveland, who described the specific reasons for the difficulties experienced by Bessemer, Mellon, Tasker, Trotz and others. From their experience, and his own, Goss emphasized that a successful die or mold material must have a high resistance to distortion and wear, have a nonwetting surface of high heat conductivity, and above all, be designed so that these advantages may be realized. To date, both copper and graphite have been successfully employed in this all important capacity.

Taking his listeners into his confidence he then illustrated several important factors, such as lubrication of the mold surface, gas separation, turbulence, mold distortion and constant metal supply by reference to the successes and difficulties he is experiencing at Duluth, where the American Steel and Wire Co. is piloting the production of 4x4-in. high carbon steel billets. The mold is built in sectional lengths, and can be adjusted to suit the cooling requirements by adding or subtracting units. A lubricant of high

conductivity is used in the form of loose or briquetted graphite. Still unsolved is the mechanical means for introducing molten metal.

Irving Rossi, consulting engineer of New York, then described the Junghans-Rossi process, of which there are now six installations in America, most of which are casting 8-in. extrusion billets of brass or aluminum, and one in England casting 16½-in. round aluminum ingots. His reciprocating mold has been greatly lengthened and modified at the Scovill installations in Waterbury, Conn., which cast 8 tons of brass per hr. A rather recent installation at Bridgeport Brass Co. is now successfully competing both as to quality and cost with conventional methods. A new feature on the latest installation for aluminum is the use of a boot at the bottom of the mold to force cooling water into the annular space between the shrinking billet and the mold wall, for increased cooling.

Although the process has been widely publicized, there are no Hazelett machines now casting sheet or strip metal, although some experimentation continues. C. W. Hazelett, the inventor, of Greenwich, Conn., discussed in detail the major difficulties which have led to the current stalemate. Roll materials are totally inadequate for casting steel strip, and no hope was held out for more resistant substances in the near future. Aluminum, brass and copper, while more hopeful, have not been successfully produced to commercial specifications for quality, rate and operating time.

The necessity for using a dam at each end of the rolls results in troublesome thermal gradients, and this, together with serious segregation, has proved to be what Mr. Hazelett described as the toughest problem he has ever come up against. The pinching action of the rolls squeezes the lower melting constituents of the alloys out of the partially formed castings, rapidly enriching the melt in these constituents and depleting it of those of higher melting point. Attempts to increase the rate of chill by raising roll pressures up to the order of 1,000,000 lb. have been unsuccessful in eliminating this effect in aluminum alloys. At the other extreme pressures as low as 200 lb. have been tried. The action desired is that which would bring two pieces of well-jellied bread gently together to form a sandwich, with as little further squeezing as possible! This neat side-step runs head-on into the result that low roll pressures and the thermal difficulties at the end dams combine to produce thick edges, forcing the rolls apart with ease.

A most impressive motion picture showed several units in operation at speeds which looked entirely convincing, but Mr. Hazelett philosophically dismissed them as "that much glitter". Present plans use ring-type rolls with coolant on the inside of a thin wall to overcome heat checking of the roll surfaces and to aid in solution of the segregation difficulties. He won a host of good wishes in his presentation of this most difficult of continuous casting techniques.

The Soro Process, as described by E. I. Valyi of Sam Tour & Co., New York, is not at all continuous in nature, but does produce cast shapes of fairly long length, dimensionally similar to continuously cast shapes. Of Swiss origin, the process as applied to rod is carried out in a centrifugal casting drum, fed with molten metal by hand poured crucible, and produces a closed ring. After severing from the runner, this is cut at one point, and straightened to produce a billet or rod. While the process appears to be limited to compositions that can be centrifugally cast in permanent molds and without undue segregation, the installation is said to be well suited to small plants.

E. R. Williams, manager of Williams Engineering Co., served as clean-up man and put on a triple-threat exhibition that necessitated ground rules when he unveiled a miniature machine and announced that he was going to do a little continuous casting in the Waldorf-Astoria Hotel! While melting progressed, his mold construction was well described — a long copper mold with thin wall. Cooling water is forced at high velocity through a thin annular jacket and molten metal is supplied the open end through a fixed orifice. Speed of casting is then adjusted to maintain a constant level in the mold. It is necessary to lubricate the working surface and this is done by a series of tubes which distribute oil to the mold wall above the metal line.

This process has been piloted by the inventor at Latrobe, Pa., and is now obtaining a trial on a considerably larger scale by Republic Steel Corp. in Cleveland. Speeds of 8 to 10 ft. per min. were cited for 4x4-in. steel billets, which emerge from the mold at a bright red heat.

Mr. Williams then cast some flat strip on his toy machine, whereupon the ground rules, if any, died a violent death, and the infield became well populated. Repeat performances brought many a satisfied grin, and the post-mortems started all over again!

The A. I. M. E. expects to publish a complete account of the entire proceedings in a future edition of *Metals Technology*, and threatens to put on a more advanced symposium next year. If this comes off the ball-room will be a likely location, judging by the present interest.

Letters From Home and Abroad

Sizes of Airframe Tubing

PITTSBURGH, PA.

To the Readers of METAL PROGRESS:

The widespread use of seamless tubing in airframe construction naturally stems from a half-century of experience — starting with the bicycle frame — with these shapes, pre-eminent in their ability to withstand combined stresses of tension, compression, bending and torsion. Demand from the aircraft industry therefore taxes the capacity of all existing tube plants, which are now being supplemented by new mills.

Fortunately for all concerned, grades of material for steel tubing were standardized, and practically all structural tubing is being specified in plain carbon (S.A.E. 1025) and chromium-molybdenum (S.A.E. X-4130), of which the latter is used in practically all but light trainer planes. (Chromium-nickel-molybdenum steel, NE8630, is now being used as an alternate material in increasing quantities.)

Unfortunately, however, standardization of *sizes* of tubing has been very difficult, and both consumers and suppliers must share the responsibility for this situation. The designer, who must get the last pound of strength and save the last ounce of weight in his structure, naturally wants a wide choice of sizes and gages, and no criticism of his actions in the developmental period of airplane construction is implied. He found that tubing manufacturers were willing to furnish almost any size and gage he specified, as they were sympathetic to his problems, and the small quantities then required involved no serious production problems.

While aircraft tubing is a special grade of cold drawn mechanical tubing, made to more exacting specifications than regular mechanical tubing, practically all producing equipment and tools used in the whole range covered in the regular mechanical tubing field were available for its manufacture. Mills were therefore readily equipped to make all sizes and gages between $\frac{1}{16}$ and $10\frac{3}{4}$-in. outside diameter, with walls from 0.004 to $1\frac{5}{8}$ in. thick. A table listing the sizes that were obtainable within these ranges included over 4300 items!

In the early airplanes only the smaller diam-

Proposed List of 205 Standard Sizes for Airframe Tubing

Wall Thickness, In.	Outside Diameter, In.																						
	$\frac{3}{16}$	$\frac{1}{4}$	$\frac{5}{16}$	$\frac{3}{8}$	$\frac{7}{16}$	$\frac{1}{2}$	$\frac{9}{16}$	$\frac{5}{8}$	$\frac{3}{4}$	$\frac{7}{8}$	1	$1\frac{1}{8}$	$1\frac{1}{4}$	$1\frac{3}{8}$	$1\frac{1}{2}$	$1\frac{5}{8}$	$1\frac{3}{4}$	$1\frac{7}{8}$	2	$2\frac{1}{4}$	$2\frac{1}{2}$	$2\frac{3}{4}$	3
0.022	22	22	22	22	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
0.028	28	28	28	28	28	28	..	28	28	28	28	28	..	..	..	..	..	..	..	..	..	..	..
0.035	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	..	35	35	35	..	..	..	..
0.049	49	49	49	49	49	49	49	49	49	49	49	49	49	49	49	49	49	49	49	..	..	..	..
0.058	..	58	58	58	58	58	..	58	58	58	58	58	58	58	58	58	58	58	58	58	..	..	58
0.065	..	65	65	65	65	65	65	65	65	65	65	65	65	65	65	65	65	65	65	65	65	65	65
0.083	..	..	..	83	83	83	..	83	83	83	83	83	83	83	83	83	83	83	83	83	83	83	83
0.095	..	..	95	95	95	95	95	95	95	95	95	95	95	95	95	95	95	95	95	95	95	95	95
0.120	..	..	..	..	..	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120
0.156	..	..	..	..	..	..	..	156	156	156	156	156	156	156	156	156	156	156	156	156	156	156	156
0.188	..	..	..	..	..	..	..	188	188	188	188	188	188	188	188	188	188	188	188	188	188	188	188
0.250	..	..	..	..	..	..	..	..	250	..	250	250	250	..	250	..	250	250	250	250	250	250	250
0.313	..	..	..	..	..	..	..	..	..	..	..	..	313	..	..	..	313	..	313	313	..	..	313
0.375	..	..	..	..	..	..	..	..	..	..	..	..	375	375	..	..	..	..	..	..	375	375	..
0.500	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	500	..

eter and lighter wall tubing were used, and only such items were shown on lists of sizes available in "aircraft" grades. These early-published lists included about 240 items, ranging from $\frac{3}{16}$ to 5-in. outside diameter by 0.022 to 0.375-in. wall thickness.

Army-Navy Aeronautical Design Standard, approved June 1940, listed but 146 items, $\frac{3}{16}$ to $4\frac{3}{4}$-in. outside diameter by 0.022 to 0.188-in. wall. Nevertheless, in 1942 the steel tubing industry was asked to make about 600 round sizes of X-4130, and over 200 round sizes of 1025.

A detailed study made in that year showed that four leading manufacturers of aircraft tubing received orders for 328 sizes of airframe tubing. Over 33,000,000 ft. was involved, of which about 95% was covered by a list of 205 sizes. This list is submitted herewith as a standard which might be adhered to without hardship for either design or production. It represents the aircraft industry's choice of sizes required to meet the major portion of all requirements. While tube manufacturers are prepared to make necessary additional sizes, it is hoped that a sincere effort will be made to conform to the list as nearly as possible. The advantage would be two-fold, namely, increased production and better deliveries.

Unfortunately, orders for non-standard sizes are almost without exception for small quantities requiring more detailed attention than the large orders for standard sizes. When 95% of all orders are for standard sizes, it is readily seen that many can be grouped, thus permitting long mill runs on individual sizes, creating a stock reservoir that can be tapped in emergencies.

Further, and of equal or greater importance, standardization of sizes permits actual stocking of finished tubing in both mills' and distributors' warehouses. If the whole industry standardized on fewer sizes the warehouse stocks would become interchangeable from one section of the country to another. Inactive and dead stocks would be reduced to a minimum. The same conditions would obtain in consumers' stocks, with a reduction of inventory and stock control problems. Identification of various sizes in the fabrication lines would also be simplified, thereby minimizing costly mistakes by inexperienced workers. The purchasing departments, too, would have their work lightened and expedited, particularly since all orders must clear through the Aircraft Scheduling Unit of the War Production Board. Jigs and fixtures, as well as fittings, would be reduced in proportion to the number of items. Aside from simplification of fabrication problems in manufacturing plants, greater advantages would be gained in widely scattered service and repair depots where parts must be available at all times to service many different types of planes.

No radical or revolutionary recommendations are being advanced. The records of the American Standards Association reveal hundreds of industries that have standardized their products, always to the mutual benefit of the producer and the consumer.

In conclusion, it should be stated that the airframe manufacturers have wholeheartedly endorsed the above recommendations. The National Aircraft Standards Committee is exploring the possibility of further reducing the number of sizes to a minimum consistent with sound aircraft engineering practices.

John W. Offutt
National Tube Co.

French Standards for Electroplates

Somewhere in France

To the Readers of Metal Progress:

The principal purpose of plating with nickel and chromium is to protect metallic parts against destructive external action, principally chemical in nature. The protective quality of such coatings depends on three factors: *(a)* Thickness, *(b)* adhesion, *(c)* continuity of the layer.

The French Standardization Association (L'Association Francaise de Normalisation, AFNOR) has now standardized various tests and methods designed for practical control of these factors, to check the protective value of the coating; for the time being the mechanical properties of the coatings have not been considered.

Following are the essential principles and conditions for these standards:

Thickness — Coatings are classified as follows: *(a)* Standard nickel plate is divided in seven categories according to the minimum thickness from 3.5 to 50 μ; *(b)* Light nickel plate, principally decorative in character, of average thickness varying from 1 to 2.5 μ; and *(c)* Standard chromium plate, divided into five categories according to minimum value of average thickness and varying from 0.1 to 1 μ.

Thickness is determined by dissolving and treating the solution, either locally (for minimum thickness) or on the entire piece (average thickness). Nickel is dissolved by nitric acid or by electrolytic etching in hydrochloric solution (for nickel plate on copper and brass) or in sulphuric solution (for nickel plate on zinc); chromium is dissolved in hydrochloric acid.

Copper is determined by electrolysis or colorimetric measurement in ammoniacal solution, nickel generally by dimethylglyoxime, and chromium colorimetrically in the form of ammonium chromate.

The "drop test" may be used as a rapid control, by determining the number of minutes necessary to reveal the underlying metal when the coating is dissolved by drops of a reagent of given composition at a temperature of 20° C. For nickel plate this reagent is a sulpho-nitric solution (one part sulphuric acid, four parts nitric acid, one part water) whose rate of solution is 2 μ per min. ($\pm$ 0.1 μ for each degree above or below 20° C.). For chromium plate a 60% hydrochloric acid solution in water is used whose speed of solution is 0.006 μ per sec. (the time being measured from the beginning of gas evolution, and the rate being corrected by $\pm$ 0.0003 μ for each degree above or below 20°).

Adherence — Two methods are available for determining adherence of nickel plate:

(a) With a chisel trace on the surface a quadrangle whose sides are about 3 mm. apart, cutting completely through the coating. No flaking or loosening of the coating should occur.

(b) Flex the piece in a vise and file in the same direction an angle normal to the bisecting plane, or file a convex surface following a tangent plane down to the metal of the base; there should be neither flaking nor loosening of the coating.

Continuity — Porosity in the coating is revealed by reagents having a visible and characteristic attack on the underlying metal at spots where it is unprotected, such as, for example, blotting paper or an agar-agar gel soaked in potassium ferro or ferricyanide, which gives a blue color with iron and brown with copper. The maximum number of colored spots is conventionally given as the number of porosities per square decimeter.

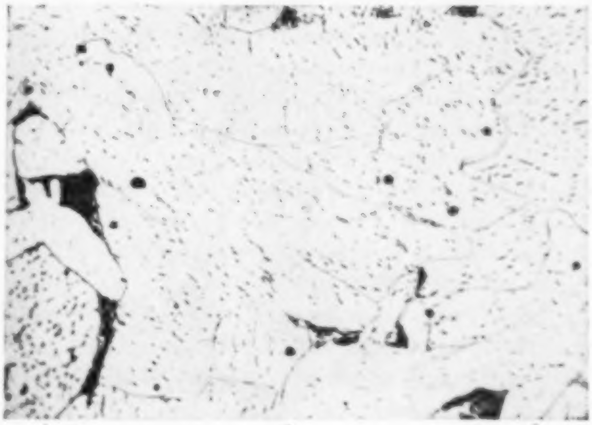
For chromium plate on nickel, attack with a solution of cupric chloride and sodium chloride gives a dull and milky appearance to the spots of bare nickel, very visible on the brilliant surface of the chromium.

Finally the salt spray test is used for aluminum, zinc and ferrous alloys, employing a solution of 3% sodium chloride and 0.3% magnesium chloride, with pH brought up to 8 by sodium carbonate.

This assemblage of tests should bring control and order into the nickel and chromium plating operations, which heretofore have not been submitted to any systematic proofs of quality.

ALBERT M. PORTEVIN
Consulting Engineer; Bessemer Medalist

A Ghost



Barney Google's Spark Plug Out in a Rainstorm

To those who do not see (or care to read) the comic strips in American papers it might be well to point out what appears to be a mule's head entering the field at the lower left corner. It is a piece of bessemer steel pipe, etched to bring out nitrides and photographed at 500 diameters.

EMIL MOLITOR
Metallurgical Dept.
Youngstown Sheet & Tube Co.

Order-Disorder in Micro-Photo Compounds

ROCHESTER, N. Y.

To the Readers of METAL PROGRESS:

Confusion in the past between the words "microphotography" and "photomicrography" and between "microcinematography" and "motion picture photomicrography" or "cine photomicrography" has led to continued misuse in the present.

Chambers's Technical Dictionary, 1940 Edition, gives the following definitions: "*Microphotography* — the production of minute prints or transparencies from normal negatives; *Photomicrography* — the production of normal negatives and prints of objects of microscopic dimensions."

Wall's Dictionary of Photography, 1940 Edition, states: "*Micro-photography* — the reproduction of photographs on a very minute scale; *Photo-micrography* — the photography of minute objects by the use of a microscope in conjunction with a camera."

In the *Amateur Photographer and Cinematographer* for November 16, 1938, the Editor writes as follows: "We shall have to get ourselves accustomed to this word, so often used wrongly. 'Photomicrography' means the enlarge-

ment of microscopic objects and the projection of the enlarged image on sensitive film. 'Microphotography' means what it says, the photography of objects on a microscopic scale."

The definition of photomicrography in Webster's dictionary as well as the above definition by Wall implies that the use of a microscope is necessary to produce a photomicrograph. A magnification of 20×, obtained with a camera lens, not involving a microscope, might reasonably be called a photomicrograph.

Misusage is spreading. In the *Transactions* of the American Society for Metals, 1941, page 733, we find this sentence: "Microradiography grew out of the desire to obtain and view radiographic images of heterogeneous objects of small size." Read the above definitions and you find the term microradiography is erroneously used; it should be reserved for use when referring to a radiograph which has been reduced in size. A good example of the latter is typified by the microfilms of chest radiographs which have been employed by the military medical branches.

A *macrophotograph,* from common usage, might be considered to be a photomicrograph made at a magnification between 10× and natural size. Metallurgists frequently use the above term when referring to photographs at unit magnification. Possibly *macroradiography* could be substituted for microradiography in the above sentence quoted.

Likewise, the term *microcinematography* has been used indiscriminately, usually when either cine photomicrography or, if you prefer, motion picture photomicrography was meant.

Elsie L. Garvin
Librarian, Eastman Kodak Co.

Spectrographic Steel Standards

Washington, D. C.

To the Readers of Metal Progress:

Those of you who are making spectroscopic analyses of iron and steels will be interested in the list of 18 spectrographic standards now available from the National Bureau of Standards. The range of compositions permit one to check important representative points of composition among several types of carbon and low alloy steels. The concentrations are sufficiently well distributed in most cases to provide analytical curves for Mn, Si, Cu, Ni, Cr, V, and Mo.

The standards are issued in two sizes—*(a)* cylindrical rod $\frac{7}{32}$ in. diameter, 4 in. long (approximately 22 g.), and *(b)* cylindrical rod ½ in. diameter, 2 in. long (approximately 50 g.). The standards are numbered in consecutive order in two series, the first beginning with 401 for the $\frac{7}{32}$-in. rods and the second beginning with 801 for the ½-in. rods. The standards may be ordered by number from the Bureau at a price of $3 each. The identifications and compositions of the standards are given in the provisional certificate below. Carbon contents are 0.1 to 0.8%.

Lyman J. Briggs
Director, National Bureau of Standards

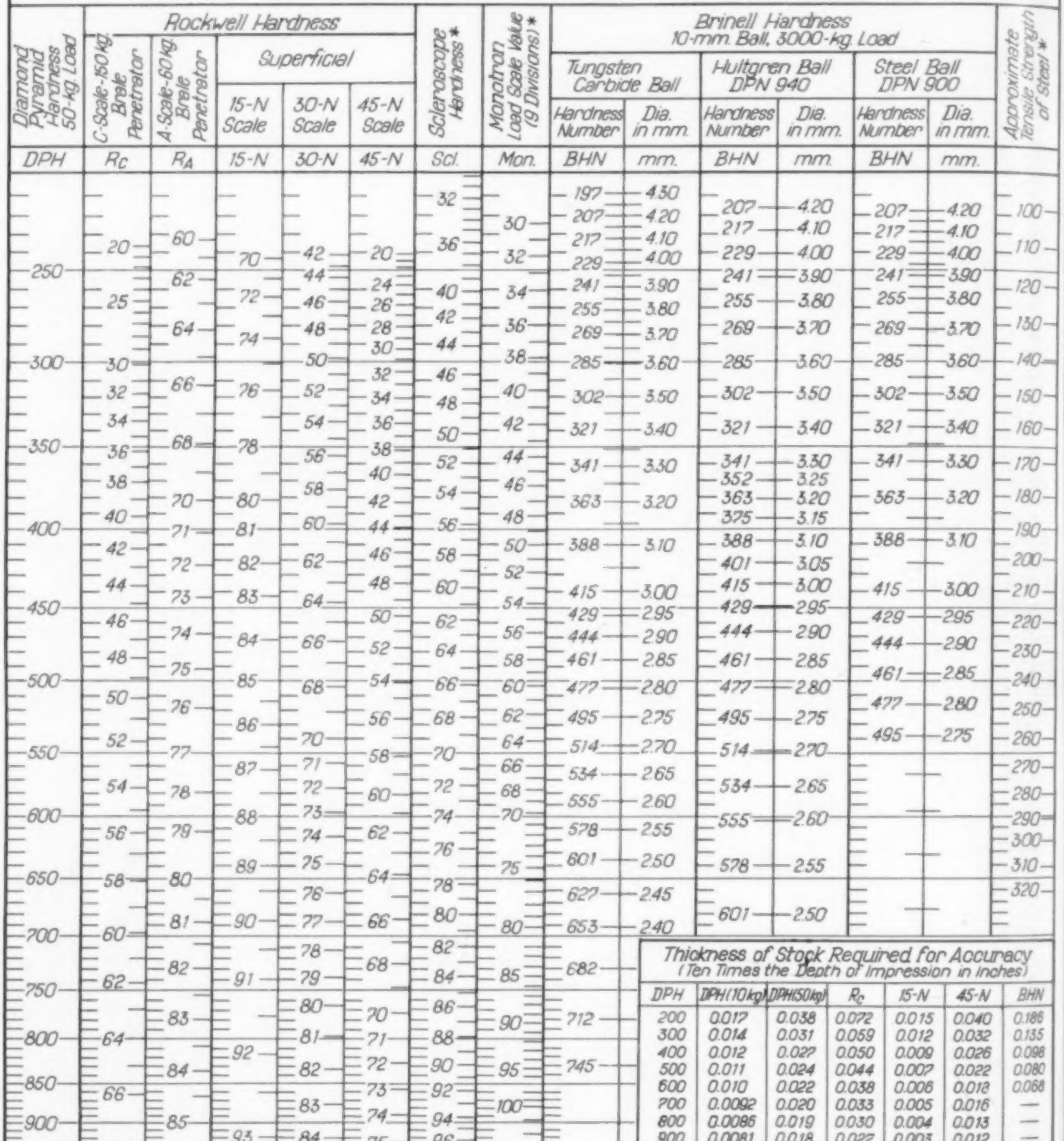
Provisional Certificate of Analyses of Spectrographic Steel Standards

Number		Name	Approximate Carbon	Certified Analysis							
$\frac{7}{32}$"	½"			Mn	Si	Cu	Ni	Cr	V	Mo	Al
401	801	Basic openhearth	0.4	0.34	0.015	— *(a)*	0.005	0.015	— *(a)*	— *(a)*	— *(a)*
402	802	Basic openhearth	0.8	0.46	0.060	0.025	0.010	0.025	—	—	—
403	803	Acid openhearth	0.4	0.89	0.25	0.16 *(b)*	0.23	0.28	0.045	0.060	—
404	804	Basic electric		—	0.35	0.21	—	0.043	—	0.006	—
405	805	Medium manganese		1.38	0.19	0.12	0.15	0.18	0.010	0.010 *(b)*	—
406	806	Chromium-vanadium		0.71	0.24	0.10	0.080	0.97	0.23	0.005	—
407	807	Chromium-vanadium		0.79	0.29	0.090	0.15	1.15	0.19	0.035	—
408	808	Chromium-nickel		0.62	0.22	0.12	1.21	0.64	—	—	—
409	809	Nickel steel		0.45	0.13	0.080	3.24	0.20	—	—	—
410	810	2% Cr, 1% Mo		0.38	0.30	0.11	0.13	2.30	0.004 *(b)*	0.97	—
411	811	S.A.E. X4130 (Cr-Mo)	0.3	0.65	0.14	0.065	0.29	0.91	0.003	0.15	—
412	812	S.A.E. 4130 (Cr-Mo)	0.3	0.60	0.22	—	—	0.66	—	0.20	—
413	813	Acid openhearth	0.4	0.67	0.22	0.25	0.18	0.055	0.007	0.006	—
414	—	S.A.E. 4140 (Cr-Mo)	0.4	0.67	0.26	0.11	0.080	0.99	0.003	0.32	—
415	815	Bessemer	0.4	1.12	0.093	—	0.010	0.010	0.007	—	—
416	816	Nitralloy G (Cr-Mo-Al)		0.48	0.25	0.14	—	1.27	0.003	0.16	1.06
417	817	Acid openhearth	0.4	0.64	0.18	—	0.105	0.028	0.004	—	—
418	818	S.A.E. X4130 (Cr-Mo)	0.3	0.52	0.28	—	0.11	0.96	—	0.22	—

(a) Dashes indicate elements not certified for spectrographic analysis.
(b) New values.

Hardness Conversions for Hardened Steel

Tentative Values Suggested by Committee E-1, A.S.T.M., Adapted From Original Work by Howard Scott and T. H. Gray, Westinghouse Electric & Mfg. Co.



Thickness of Stock Required for Accuracy
(Ten Times the Depth of Impression in Inches)

DPH	DPH (10 kg)	DPH (50 kg)	R_c	15-N	45-N	BHN
200	0.017	0.038	0.072	0.015	0.040	0.186
300	0.014	0.031	0.059	0.012	0.032	0.135
400	0.012	0.027	0.050	0.009	0.026	0.098
500	0.011	0.024	0.044	0.007	0.022	0.080
600	0.010	0.022	0.038	0.006	0.018	0.068
700	0.0092	0.020	0.033	0.005	0.016	—
800	0.0086	0.019	0.030	0.004	0.013	—
900	0.0081	0.018	0.027	0.003	0.012	—
1000	0.0076	0.017	0.025	0.003	0.010	—

Monotron tests at all hardnesses can be made on 0.018-in. stock. Scleroscope numbers vary with size; relations given are for 1-in. pieces.

* *From Westinghouse Standard S 502.1*

In operating any test machine, follow manufacturer's instructions and check frequently against test blocks. Major causes of discrepancy: *(a)* Decarburized skin, *(b)* specimens too thin, *(c)* off-standard indenters, *(d)* inaccuracy of machine.

Above conversions are for steel, irrespective of composition and structure, up to its maximum hardness, and for any other material having about 30,000,000 psi. elastic modulus, uniform in depth to bottom of impression. (An exception is that Rockwell test values for shallow hardened steel may be 1 or 2 points higher than by conversion from *DPH*.)

For sintered carbides (*DPH* 900 to 1700) with much higher modulus the relations between *DPH* and R_c may be computed from $DPH = \frac{2.445 \times 10^6}{(B - R_c)^2}$ wherein constant B is 118 for carbide (120 for steel).

Ben Shepherd, Past President ⊕, has devised a chart correlating Jominy end-quench data with cooling speeds, surface and center, for specific quenching conditions, and the size of bar that can be completely hardened, and in this article he shows some of its utility

Amount of Martensite

in quenched steel influences

Properties After Tempering

By Benjamin F. Shepherd
Chief Metallurgist
Ingersoll-Rand Co.
Phillipsburg, N. J.

IN a continuing study of the relationship between microstructure of quenched steel and the best combination of physical properties in a quenched and tempered piece, we have found the chart, Fig. 1, to be of great help. It can be used readily to derive the relation between the end-quench hardenability of a given heat of steel (Jominy test) and "critical hardenability" — that is, the diameter of bar that will have a 50% martensitic structure at the center after quenching in still oil. (This is not the same as Grossmann's "ideal hardenability", which is the diameter of a bar that will harden to 50% martensite at the center, *when quenched in an ideal quenching medium* — one which brings the surface of the steel to its own temperature *instantly*, and holds it there.)

The chart, as given, applies to a quench in still oil, but it will be apparent that the curves for cooling rates vs. bar diameters can be changed to apply to similar conditions for any commercial quench in use or under study. Such data are recorded in the American Iron & Steel Institute's "Contributions to the Metallurgy of Steel", No. 7, and may also be plotted according to principles

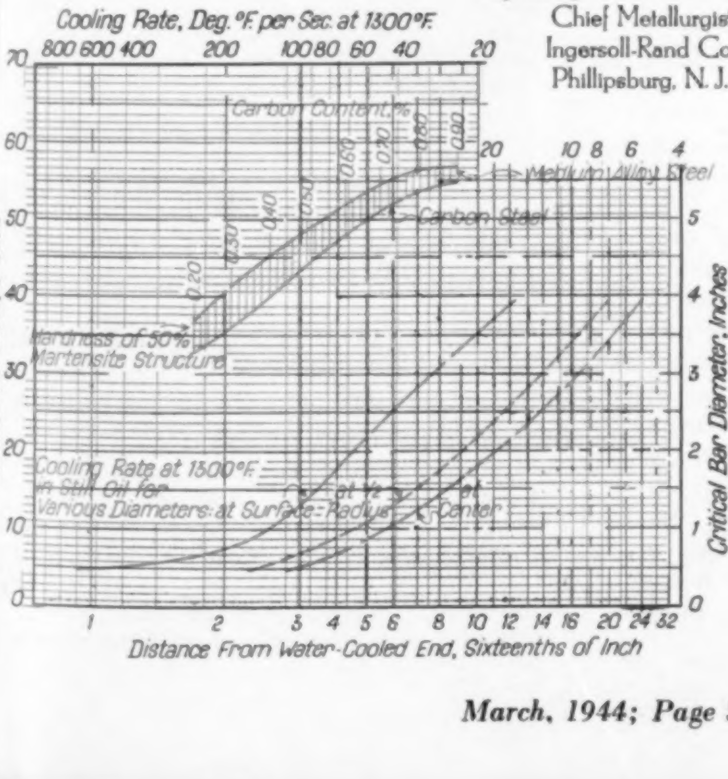
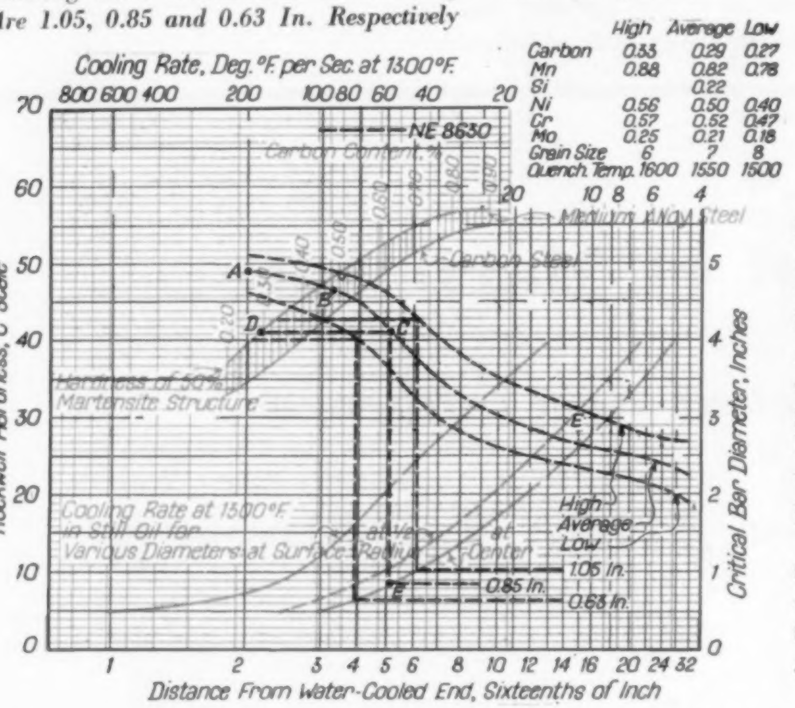


Fig. 1 — Relation Between Hardness of Steels of Various Carbon Contents, and Diameters of Bars Having Ideal Hardenability — 50% Martensite at Center — After Quenching in Still Oil. (Diagram copyrighted by Ingersoll-Rand Co.)

Fig. 2 — Jominy End-Quench Curves for Maximum, Average and Minimum Heats of NE 8630, and Construction Lines Showing That Critical Bar Diameters for Still Oil Quench Are 1.05, 0.85 and 0.63 In. Respectively



expounded by Grossmann and Asimow in a paper entitled "Hardening Characteristics of Various Shapes" (*Transactions* of the American Society for Metals, December 1940, page 949).

Figure 2 shows how the chart will interpret the Jominy test. Curves for the latter were taken from a publication of the American Iron and Steel Institute giving information about the NE steels. Three curves show the maximum, minimum and average hardenability of 13 tests on 8 heats of NE8630, and may therefore be regarded as representative commercial practice.

Let us fix our attention on the average curve *A-B-C*. Carbon content of this average steel is 0.29%, so the horizontal construction line *D-C* starts at point *D*, the hardness (C-41) of a 50% martensitic structure in a medium alloy steel containing 0.29% carbon. This horizontal intersects the Jominy end-quench curve at point *C*, where the hardness is C-41, and the cooling rate at 1300° F. to give that hardness is represented by the vertical *C-E* through point *C*. Point *E*, falling on the curve representing cooling rates in still oil at center of various sized bars, marks the "critical bar diameter" of 0.85 in., which by definition is the size that will harden to a 50% martensitic structure at the center during a quench in still oil. (In practice a "fully hardened" steel must contain at least 50% martensite.)

Similar geometric constructions, starting from the carbon analysis in the high and low heat in this series, bring out immediately that round bars as large as 1.05 in. in diameter will harden through giving 50% martensite at the center when quenched in still oil in the most hardenable heat, and as little as a 0.63-in. bar in the least hardenable heat. Correct and best utilization of commercial material which has a hardenability ranging between these limits obviously requires some simple means of discovery and control. It is sound practice to assign material on the basis of the minimum hardenability which would be encountered in any particular heat.

This variability is not limited to NE8630, nor indeed to the NE steels as a class. Further examples taken from the above mentioned A.I.S.I. publication are for four NE

Fig. 3 — End-Quenched Bar Is Flattened on Four Sides, Sliced as Shown, Hardness Rechecked, Portions Tempered at 500, 800, 1000 and 1200°F., Respectively, and Hardnesses Again Measured

steels as noted below. These figures were obtained with the aid of the chart, Fig. 1, by construction lines drawn as explained for Fig. 2, and represent hardenability in still oil quench:

Steel	Critical Bar Diameter High	Average	Low
NE8339	1.5 in.	1.2 in.	0.8 in.
NE8442	2.3	1.7	1.4
NE8739	1.8	1.5	1.15
NE8744	1.9	1.65	1.3

In addition to getting a very direct answer

in terms of bar sizes to indicate the correct utilization of commercial heats, we have used the charts to show some interesting facts about the effect of tempering temperatures. Hardness of the drawn object is not a constant function when the material is harder than the 50% martensitic structure; it is a function of the amount of martensite present, the carbon content of this martensite, and the inherent hardenability of the material.

To show this we have taken Jominy bars and sliced them by careful work in an abrasive wheel into five sections as shown by Fig. 3, then drawing one piece to 500° F., one to 800° F., one to 1000° F., and one to 1200° F. We used the extra section for examining the microstructure. All of these sections are rechecked for hardness before tempering.

Results of this sort for a heat of NE9450 are given in Fig. 4. Drawing construction lines as explained in Fig. 2, we find the critical bar diameter for a still oil quench to be 3.2 in. (Point *A*), and hardness at center is C-48.5 (Point *B*). The diagram also indicates that the cooling rate at the surface of this bar is 26° per sec. at 1300° F. (Point *C*), and the hardness at the surface is C-58 (Point *D*).

It will be noted that the hardness-length curves of the tempered specimens are flat for a considerable distance, and that the points where softening starts fall pretty close to a straight line, shown dotted as *E-F-G-H*.

Project one of these points (*F*, on the 1000° temper curve) vertically downward to intersect with the curve for center cooling rate and we get Point *J*, corresponding to 2.2 in. critical bar diameter. This means that bars of any size up to 2.2 in. may be tempered completely at 1000° F.; that is, their surface hardness will be C-37 and their center hardness C-36½ (Point *F*). Center hardness of a larger bar (say the 3.2-in. bar) will be C-34 (Point *K*).

In similar ways the maximum sizes for complete tempering, surface and center hardnesses, are derived from Fig. 4 for the table at the head of this column.

Table I — Tempering Data for NE9450
Critical Bar Diameter: 3.2 In. for Still Oil Quench

Tempering Temperature °F.	Diameter Bar Quenched (In.)	Expected Hardness	
		Surface	Center
1200	3.2	C-28½	C-27½
1000	3.2	37	34
	2.2 and under	37	36½
800	3.2	47	43
	1.55 and under	47	47
500	3.2	54★	45½
	1.15 and under	55½	55
None (as quenched)	3.2	58	48½†

★Since the surface hardness of the 3.2-in. round is only C-58 (Point *D*) this is probably insufficient to respond *uniformly* to a hardness of C-55½ after tempering to 500° F. C-59 (minimum) would be needed as quenched.

†This is the "critical hardness" of the steel — that is, the hardness of a 50% martensitic structure.

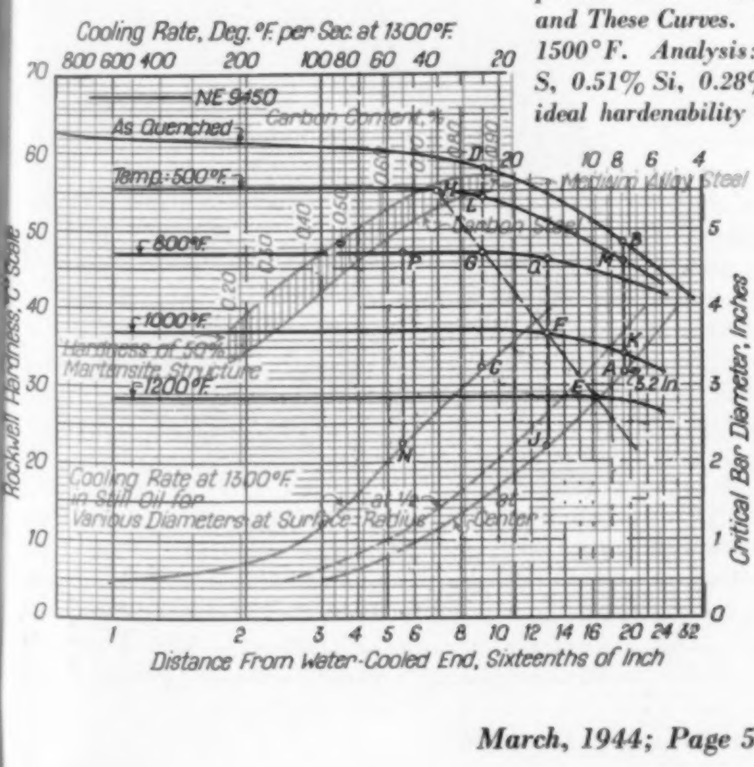


Fig. 4 — Jominy Bar of NE 9450 Tempered to Various Temperatures and Hardness Re-Surveyed, Gives Data for Table I and These Curves. Steel normalized at 1550 and quenched from 1500°F. Analysis: 0.49% C, 1.36% Mn, 0.022% P, 0.031% S, 0.51% Si, 0.28% Ni, 0.32% Cr, 0.10% Mo; grain size 7; ideal hardenability 4.6 in. calculated, 4.7 in. from end-quench

Another way of stating this information is to say that if uniform hardnesses of approximately C-47 are required, 1½-in. round is the maximum bar size which can be used and the same effect attained. On bars increasing in size from 1½ to the critical bar size (3.2-in. round) the tempering temperature would have to be progressively reduced in order to maintain the C-47 Rockwell hardness in the center of the bar.

Figure 4 can also be used to determine the condition at surface and center of *any* size of round bar

after quenching and tempering at the indicated temperatures.

For example, consider a 3.2-in. bar tempered at 500° F. Its surface cooling rate during quenching is noted at Point *C* and its center cooling rate at Point *A*. Verticals through these points intersect the curve for specimen tempered at 500° F. at Points *L* and *M*, Rockwell C-54 and C-45½ respectively for surface and center (as shown in Table I). Note that both Points *L* and *M* are to the right of the dotted line *H-E*. A little consideration indicates that the surface as hardened was not fully martensitic, and it will be shown that the hardness after tempering will be less than that which would be expected from a structure originally 100% martensitic.

Next consider a 2.2-in. round tempered at 800° F. Surface and center cooling rates are noted at *N* and *J*, and hardness after tempering at surface and center is C-47 and C-46 respectively (Points *P* and *Q*). Note that one of these points is to the left and the other to the right of dotted line *H-E*, which indicates that the surface, as hardened, was about 100% martensitic, but the center wasn't — hence the difference between the tempered hardness surface to center.

Finally, consider a 1.75-in. round tempered at 1000° F. Points representing tempered hardness both fall to the left of the dotted line *H-E*, the steel is uniformly hard (C-37) after tempering, and the entire bar was completely martensitic after quenching.

Representative structures are given in Fig. 5, 6, and 7, magnified 1000 dia., of the surface of the Jominy bar at the hardened end (100% martensite), at Point *D* (80% martensite), and Point *B* (50% martensite). As soon as ferrite appears in the microstructure the tempering temperature required to maintain the same hardness, surface to center, must be increased.

We are becoming increasingly aware of the fact that the maximum combination of physical properties can only be attained by the use of structures which are approximately 100% martensite *as hardened* — that is to say, structures containing no other transformation products. Determinations of *true* proportional limit* on as-hardened structures show very graphically the influence of even a small percentage of free ferrite. Very remarkable combinations of high mechanical strength with excellent ductility are possible in steels quenched without producing free ferrite — a matter worthy of discussion in a separate paper.

*Throw "yield point" (as determined by the drop of beam) out the window!

Fig. 5 (Top) — 100% Martensitic Structure at Hard End of Jominy Bar (Steel NE 9450); Nital Etch; 1000 Diameters. Fig. 6 (Middle) — 80% Martensitic Structure at $\frac{9}{16}$ In. From End of Jominy Bar (Point D of Fig. 4). Fig. 7 (Bottom) — 50% Martensitic Structure Giving "Critical Hardness" (Point B, Fig. 4)

Hardness, surface and center, of NE9450 steel bars of any size, tempered at any temperature, can be derived

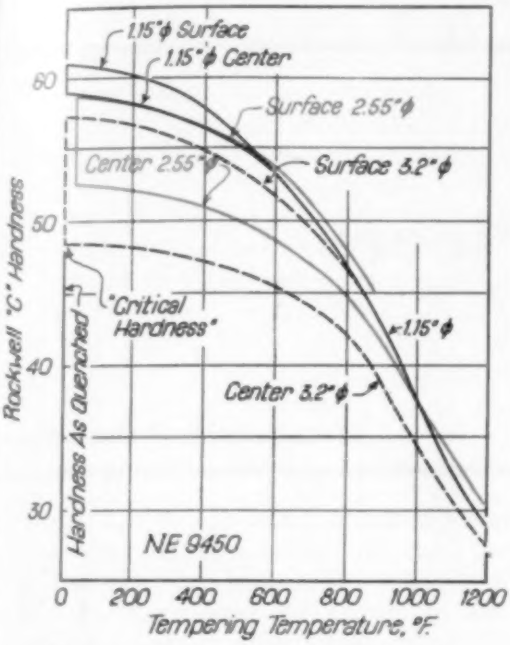


Fig. 8 — Rockwell Hardness (Surface and Center) Versus Tempering Temperature for Various Sizes of NE9450 Steel, Quenched From 1500° F. in Still Oil

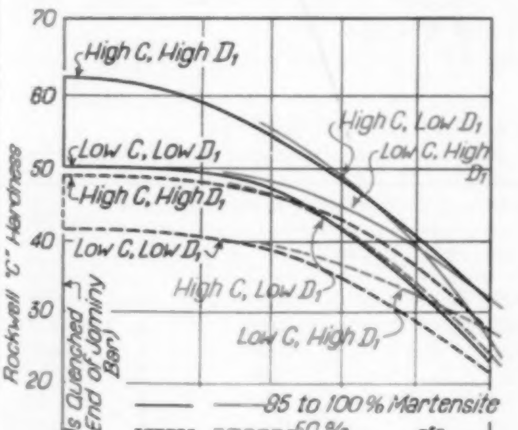


Fig. 9 — Influence of Carbon Content, Ideal Hardenability and Proportion of Martensite in the Quenched Microstructure on the Hardness After Tempering. Steels investigated:

Type	C	D_1 (calculated)
8749	0.47%	6.19 in.
X4340	0.38	5.22
X4340	0.41	5.18
9450	0.49	4.55
9430	0.30	3.10
8630	0.31	2.94
4037	0.33	1.95

from Fig. 4 in the manner indicated in Fig. 8. The surface and center hardness for given bars (in this case 1.15, 2.55 and 3.2 in.) as quenched and after drawing at 500, 800, 1000 and 1200° F. were plotted with smooth curves connecting them. The top pair of lines, in black, show that all sizes up to 1.15 in. diameter will have a uniform hardness throughout after tempering to 500° F. or higher. The intermediate pair of lines, in red, show similarly that 2.55 in. is the largest diameter of NE9450 that can be given a uniform hardness, surface to center, and to do this requires tempering to at least 1200° F. Finally the bottom pair of lines, in black, are for the "critical bar diameter", and show that hardness gradients, surface to center, will exist at all tempering temperatures.

Remember that the above quantities refer to NE9450 steel quenched in still oil, but the method is general and can be applied to any steel and any quench, if the Jominy bars are measured before and after tempering, and if the speed of cooling — or intensity of quench — is known.

Steels More Resistant to Tempering

Curves such as Fig. 8 were worked out for a series of standard steels and it was found that the martensite formed by a steel having a high ideal hardenability D_1 as calculated from the chemical composition by Grossmann's methods is more resistant to breakdown by tempering temperature, regardless of the percentage of martensite formed. This fact is shown in Fig. 9, and the divergence between lines for high ideal hardenability and low ideal hardenability is quite consistent. The steels investigated in forming this chart are listed in the caption. Fairly good accuracy in predicting hardnesses after tempering other steels, graded as to carbon content and hardenability, may be had by interpolation.

These experiments show that a great many of the published tests showing the relationship between mechanical properties, strength and hardness and tempering temperature give a very wrong impression. Tests of this character are only good for the particular percentage of martensite that existed in the tensile test section as quenched. Percentages of martensite lower or higher than this will give different physical properties, particularly at the lower tempering temperatures.

Comparisons are being regularly made between vitamin treated "needled" or "intensified" steels and the base material without special treatment in the ladle. Due to the high hardenability of the treated steel it will, in general, have a greater percentage of martensite in the as-hardened structure and will show higher mechanical properties, particularly at low tempering temperatures. Every comparison of this sort should be accompanied by a statement or photomicrograph indicating the as-hardened hardness and the percentage of martensite in the bar before tempering.

This department, "Bits and Pieces", welcomes notes concerning new ways of doing things to metals, either in shop or laboratory. An ⊕ book of your choosing (other than the Metals Handbook) is the reward for a publishable item

Bits and Pieces

Metallurgicus' Own Pages

Cycle Annealing—II

LET'S GET DOWN TO BUSINESS on this matter of cycle annealing and see how it is best carried on in mass production, and how we may approximate the same results in a small heat treat with limited equipment:

First — a typical annealing cycle. One of the meanest steels to anneal to uniform hardness and uniformly satisfactory machinability is S.A.E. 4150, which has been widely used for many ordnance ballistic items in sizes from 1½ to 4½-in. round. If purchased "annealed" from steel mills, the structure will vary from full pearlite to full spheroidized, hardness from 160 to 255 Brinell. (I don't mean to condemn the steel mill, which has to work with all-purpose furnaces on a heavily overloaded schedule.) For any one structure and hardness a machining procedure can be set up which will give acceptable results, but such variations as cited above are hard to accommodate, even in a shop with wide-awake supervision. Jominy hardenability above C-55 may vary in this steel from ¾ in. to over 2½ in., which gives a clue as to why the mill annealed structure is so variable.

As compared to the results of full annealing (furnace cool) cited above, a suitable cycle anneal conditioned heat after heat of this steel to a structure of about 75% lamellar pearlite, 25% partially spheroidized, with Brinell hardness of 197 to 229 (usually 205 to 212) and excellent uniformity of machinability. The cycle was about as follows: Heat to 1500° F., holding 1 hr. at heat; cool quickly to 1300°; hold at 1300° for 4 hr.; then cool in any convenient way. Short, simple and effective!

The adjoining table contains the cycles sug-

Payson's Short Annealing Cycles

Fairly rapid cooling between austenizing and transformation

Steel	Austenizing		Transformation		Resulting Hardness
	Temperature	Time	Temperature	Time	
3130-3150	1425° F.	2 hr.	1250° F.	2 hr.	163/174
3240	1425	2	1260	2	187/192
3312, carburized *(a)*	1380	1	1100	1	230/250
3312, forgings *(b)*	1725	3 *(c)*	1100	4	217/241
4042	1500	2	1250	2	179
4130-4140	1425	2	1300	2	170/192
4150 *(d)*	1500	1	1300	4	197/229
4155 *(e)*	1480	2	1350	4 *(e)*	183/212
4320-4342	1425	2	1210	8	163/235
4640	1370	2	1210	12	187
52100	1440	4	1340	4	197/207
6150	1425	2	1310	4	192
8620; 8720	1600	1	1250	2	143
9260	1450	2	1360	4	212

(a) C. W. Dietz; *Metal Progress*, December 1943, page 1097.

(b) Dodge-Chicago practice to eliminate banding; *Metal Progress*, January 1944, page 108.

(c) Air cool to 1000° F.

(d) Metallurgicus.

(e) Walter Hildorf; *Metal Progress*, June 1942, page 811, who recommends slow cooling (10 to 15° per hr.) from 1350 to 1200° F.

ested by Payson in the articles referred to last onth for many different alloy steels, some of hich are difficult to condition by any other eans. Another bad actor, carburized 3312, was iscussed by Dietz in December *Metal Progress.*

Now as to the actual operation: The above xample indicates the requirements; the steel ust be heated uniformly to the austenizing temperature, then cooled rapidly and uniformly to he transformation temperature (not lower) and inally held at this level for the required time.

Because of the need of uniformity, continuous furnaces in which every piece goes through he same cycle are of course preferable. In such quipment, the rapid cool is given by carrying he work (on trays or by conveyor) out of the igh heat zone either into an open, air-cool section or through a baffled opening into an adjacent urnace zone equipped with cold water "radiators" which rapidly extract heat. The work is hen carried into the intermediate temperature one for transformation. Push or travel rate and oading must be balanced so that the "rapid cool" art of the cycle (which is relatively inflexible) has the required effectiveness. Cooling must not be too rapid, or the surface of the work will cool oo low before the interior comes down to the required temperature; for moderate sections not ightly loaded but properly racked up, still air ooling will usually take the heat away from the urface at somewhere near the same rate at which it is traveling from interior to surface, and no high thermal gradients will be produced.

(Note that "quenching" is not desired lthough this does not rule out the scheme of sing two salt baths, one at austenizing temperature and the other at the transformation temperature. Two things should then be borne in mind: *(a)* The same salt should be used in both ots, or compatible mixtures, and *(b)* the second ath may have to be cooled to remove the heat rought in by the work — as with "austempering", of which cycle annealing is blood brother. Salt baths are especially adapted to small pieces.)

This description should indicate how cycle nnealing can be done in batch furnaces. Steel arts loaded on trays or even just charged onto he furnace hearth are heated to the austenizing emperature for the required time; then the trays are pulled out into air (or the pieces raked out of the furnace) and allowed to cool to the transformation temperature; then the work is put into nother furnace at the transformation temperature. Exploration with a thermocouple will readily establish the proper air-cool time for loads of elected size. Time for the cooling part of the ycle may usually be around 30 min., but a study of the TTT curves given by Payson or in the Steel Corporation's Atlas will show whether there is any danger in being more deliberate with any particular steel.

It is rarely possible to cool a box furnace fast enough to permit carrying on the whole cycle in one furnace, but I believe cycle annealing is feasible in such a furnace as the Lindberg Super-Cyclone where there is forced circulation and but small reservoir of heat.

Cycle annealing offers the best current answer on most common alloy steels to the problem of getting uniformity of hardness, structure, and machinability, and at the same time provides a great saving in time (and hence of equipment and scaling loss) over conventional furnace-cool annealing.

I hope this discussion leads to wider use of cycle annealing in small heat treating departments, and that operators who have worked out cycles using simple equipment will report them and so help others.

METALLURGICUS

Machining Coarse-Grained Zinc

WHEN coarse-grained zinc is machined, cleavage fractures occur in some of the grains. These are avoidable by keeping the zinc above the temperature of boiling water, since the metal is not susceptible to cleavage when hot. Too high temperature, above 500° F., should be avoided since some grades of zinc fail by hot shortness at these temperatures. Commercial wrought zinc products and zinc alloy castings are fine grained and can be machined safely at ordinary shop temperatures. (GERALD EDMUNDS, Research Division, Technical Department, The New Jersey Zinc Co.)

Doubling Cassettes in Emergencies

TO MEET EMERGENCIES, when the radiographic department is pressed with work near the upper limit of its X-ray equipment, and thus requiring the use of intensifying screens, the following scheme will double the number of film cassettes available:

Cassettes normally have screens in sets of two, one mounted in front and another in back, so they are on both sides of the sensitive film. If these intensifying screens are "unmounted" — loose, so they can be replaced when exhausted — one of them can be removed and inserted in a cardboard exposure holder, placing the screen on

the film side opposite the lead back. In this manner one set of screens may be used for two exposure holders. The time of exposure will be increased, but not excessively, with the amount of increase depending on the technique and type of film used. The increase in exposure time may be determined easily by a few sample exposures and noted for future use. The loss in definition is not too great. (B. A. KORNHAUSER, Washington, D. C.)

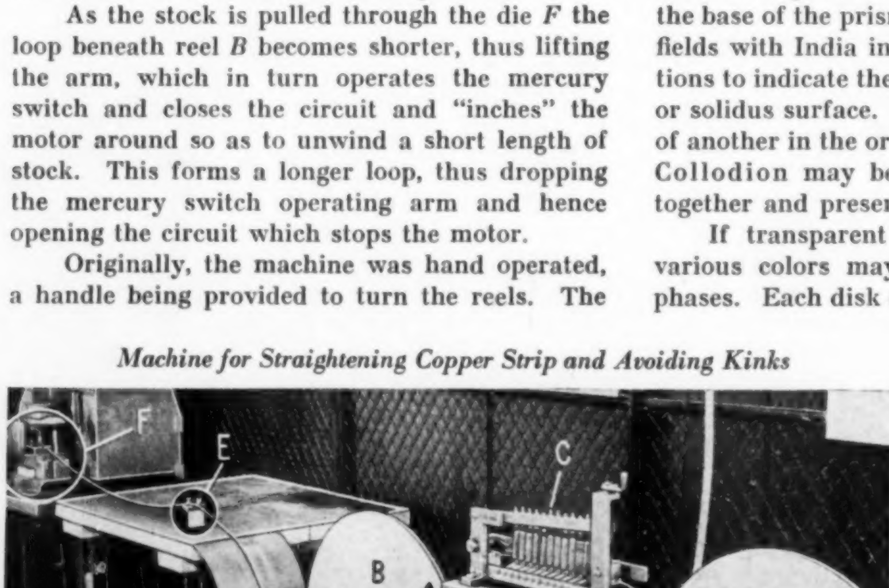
Automatic Control of Punch-Press Feed

A SIMPLE application of a mercury switch has enabled us to hook up a relatively high speed straightener to a punch press requiring a slow supply of straightened strip. Formerly this required continuous attention by the press operator. In the view, power-driven reel *B* draws copper strip from coil *A* through straightening rolls *C*. The full reel *C* then delivers strip through wiper *E* to punch press *F*. To prevent over-run of stock, the straightened strip is looped nearly to the floor and passed through a hinged stirrup which acts as a handle to mercury switch *D*.

As the stock is pulled through the die *F* the loop beneath reel *B* becomes shorter, thus lifting the arm, which in turn operates the mercury switch and closes the circuit and "inches" the motor around so as to unwind a short length of stock. This forms a longer loop, thus dropping the mercury switch operating arm and hence opening the circuit which stops the motor.

Originally, the machine was hand operated, a handle being provided to turn the reels. The stock was run through the rolls from the reel on the right to the reel on the left. The left reel was then moved over to the right side and the stock run through the rolls again. The stock was then pulled off the reel and cut into pieces about 10 ft. long and fed through the punch-press die. Considerable time and material was wasted doing the operations prior to the final cutting off. (K. J. STEINER, Small Motor Division, Westinghouse Electric & Mfg. Co.)

Machine for Straightening Copper Strip and Avoiding Kinks



Model Construction

BITS AND PIECES asked, in January, for suggested methods for making models which would illustrate the equilibrium conditions or structural phases existing in ternary systems.

An illustrative model might easily be made of transparent plastic plate. A number of triangular sections of uniform thickness would be cut, each section to represent a predetermined temperature interval. (A section ½ in. thick may equal 100° F. or 200° F., depending upon the desired size of the model.) Starting with the lowest temperature section to be illustrated, as the base of the prism, block out the various phase fields with India ink. Shape the succeeding sections to indicate the change in contour of liquidus or solidus surface. Place the sections one on top of another in the order of increasing temperature. Collodion may be used to hold the sections together and preserve transparency.

If transparent colored plastic is available, various colors may be assigned to the several phases. Each disk can be made of various colors, with jig saw, draw knife and rasp, to distinguish the various phases.

For temporary use an opaque model can be made of colored modeling clay, formerly obtainable in any department store, but replaceable by a mixture of fine china clay, vaseline, and dry color. The consistency of the clay is adequate to retain its molded shape for several weeks. Soap is also a good substance for easy carving.

If one is adept at soldering, a model can be built of stiff wire. Three two-component fields are first laid out on a flat surface.

Wire is used to represent the phase boundaries. The three layouts, after soldering, are set upright and held together by adding horizontal tie wires representing temperature gradients. The surface of liquidus or solidus or phase boundaries may then be indicated by using colored silk thread attached from one wire to another in the completed model. (E. M. SMITH, Operating Engineer, Aluminum Co. of America)

Keep Water Out of Fast Quenching Oils

IT IS A WELL KNOWN FACT that when an oil-in-water type emulsion is used for quenching steel the cooling rate through the transformation zone is slower than the cooling rate of either the oil or water alone. However, it was surprising to us in the Springfield Armory to find that as little as a few tenths of a per cent of water, finely dispersed in a normally "fast" oil, so reduced the initial quenching speed of the oil that it no longer quenched satisfactorily.

This pronounced effect of a small amount of water became apparent when quenching trouble developed suddenly and without apparent change in heat treating procedure. Metallurgical examination of the steel revealed a microstructure which probably resulted from subcritical cooling rates, which in turn suggested that the source of the trouble might be found in the quenching system. Analysis of the oil showed nothing abnormal except the presence of 0.3 to 0.4% of water. However, laboratory quench tests on the oil showed considerable reduction in the initial quenching speed as measured by the "5-sec. quench test". The answer to the problem became clear when the originally high initial quenching speed was restored to the oil simply by driving off the water at 220 to 230° F.

Further tests have since demonstrated that this effect of a small amount of suspended water is characteristic of at least three commercially available oils, all of which normally show high initial quenching speeds. This relationship is shown in the adjoining table, where the per cent of suspended water, determined by distillation, is noted against the initial quenching speed as measured by the 5-sec. quench test. Data were obtained by making quenching speed tests and water content tests on samples of oil into which water was artificially introduced as steam. Good emulsions were easily obtained and appeared to be stable for several days. Particle size was uniform with an average diameter of approximately ten microns (0.00039 in.). Following the tests, each sample of oil was dehydrated at 220 to 230° F. and in each case the original quenching speed was restored.

At about 1% water concentration the quenching speed of all three oils approaches that of uncompounded low viscosity mineral oil, the water having completely offset any benefit which may be derived from added "quenching-speed-improving factors". The explanation seems to be simple although perhaps not readily predictable: The small amount of water which comes in contact with the quenched piece forms, immediately on quenching, a persistent water vapor blanket which offsets or neutralizes the accelerated quenching action of additives to the oils. The effect is therefore to prolong the duration of the so-called "A" or vapor cooling stage of the quench, and thus decrease the initial quenching speed of the oil.

The 5-sec. quench test may not be familiar to some readers:

Two identical samples of oil are placed in well insulated beakers. Into one sample a 2½ by 1-in. round steel test plug is fully quenched, and into the other a similar piece at the same temperature is quenched for 5 sec. only. The temperature rise for each sample of oil is determined by thermometer as accurately as possible. The value for the quenching speed of the oil is equal to the temperature rise for the 5-sec. quench divided by the temperature rise for the full quench multiplied by 100. The higher the value obtained, the greater is the cooling rate of

Tests on Three "Fast" Oils

	OIL A		OIL B		OIL C	
	Physical Properties					
Flash point, C.O.C	360° F.		360° F.		365° F.	
Fire point, C.O.C.	405		405		410	
Viscosity, S.U.S. @ 100° F.	110		110		139	
Neutralization number	0.1		0.3		0.3	
	Quenching Tests					
	WATER CONTENT	SPEED	WATER CONTENT	SPEED	WATER CONTENT	SPEED
	0.0%	42.5%	0.0%	43.0%	0.0%	36.5%
	0.15	30.0	0.5	32.0	0.6	28.5
	0.4	26.5	1.0	24.5	1.1	20.0
	1.0	16.5				

the steel plug from 1500° F. to whatever temperature may be reached in 5 sec. Test plugs are usually dull red or nearly black; probably somewhere in the range 900 to 1200° F. depending on the quenching speed of the particular sample being tested. Temperature of test plugs is not critical, as long as they are identical. (GEORGE R. PEASE, Associate Chemist, Springfield Armory)

Notch Bend Test for Thin Stock

MANY TIMES a sample of steel to be tested for notch toughness is too thin for a standard Charpy or Izod bar. Various kinds of pipe and flat stock are examples, and if one wishes to know how the pipe is apt to behave with a screw thread on the end or the flat stock when blanked and formed, for example, the test devised by Heyn is very useful:

With ⅛-in. thick material, a flat specimen is prepared about ⅜ to ½ in. wide and 2 in. long. A transverse notch is filed at the center of the broad face about one-third through the thickness, using a sharp triangular file. The test consists of holding the specimen in a vise and hammering the free end through a 90° bend to open up the notch, then bending it back straight, and repeating the process until fracture occurs. A "good" steel will take about four 90° bends, while a "poor" steel will snap off with the first blow or two, so that the spread in results is quite wide. (In both cases, it should be realized, the samples would bend 180° flat on themselves if no notch were used.)

With thicker stock the notch should be cut deeper to preserve the same ratio of thickness below the notch to width of sample. It is always well to try preliminary tests on steels with high and low notch sensitivity for direct comparison with the steel under test. (S. L. HOYT, Battelle Memorial Institute)

Time Saver in Dark Room

THE NOTE on page 95 of July 1943 "Bits and Pieces" recommends a copper coil through which cold water is circulated for cooling developer solutions. Our tests have indicated that traces of copper salts in a developer may cause serious fog. The quantity of copper ion transferred to the developer would depend on the time of immersion and the degree of corrosion of the copper piping when not in use.

It is recommended, therefore, that the copper coil be silver plated and that the plating be renewed whenever green copper salts are visible on the surface of the coil.

The most satisfactory construction material is molybdenum stainless steel (Type 316 or 317) but the following materials, in most cases, would be satisfactory: Stainless steel (Type 304), inconel, nickel, monel, and lead. (J. I. CRABTREE, Research Laboratories, Eastman Kodak Co.)

Early Detection of Fatigue Cracks

RECENT ISSUES of "Bits and Pieces" have had suggestions on the early detection of fatigue cracks, such as a thin film of penetrating oil and fine dust of Fuller's earth, or more simply a mere soap solution. Several years ago, I was studying the fatigue properties of various lead alloys used for cable sheathing. In order to detect the formation of fatigue cracks at an early stage in the test, I removed specimens from the fatigue working machine and stretched them slightly (not over 5%) in a tensile testing machine. This had the effect of widening cracks which were present so that they could be clearly seen by eye, or with a pocket magnifier. In many instances, the depth of cracks could be estimated and the relative merit on complete fatigue tests could be predicted from specimens run only about 10% of their normal fatigue life. (LAWRENCE FERGUSON, Bell Telephone Laboratories)

The Resin Method of Indicating Yield in Metals

ANOTHER method for indicating locations where metal is in distress, at an early stage in the test procedure, has been published by J. S. BLAIR in *The Engineer*. The method is recommended for complicated stress systems in large structures at atmospheric temperatures, having been applied, for example, piecemeal to a 100-ft. truss span. The resin coating must be as brittle as possible; small pieces can be dipped in melted resin at 280° F., held there until the metal is up to temperature and drained. Large structures should be cleaned of paint and coarse scale, heated locally by blowpipe to 280° F., and the resin dusted on, or the hot part merely rubbed with a lump. If the temperature is too high the resin will burn, or drain too completely; if too low the resin sticks and will not properly wet the surface. Progress of yield in the metal can be clearly followed by watching for fine cracks, which broaden, spread, and appear in other places.

Personals

R. M. GARRISON ⊕, formerly chief engineer of the Mission Manufacturing Co., Houston, Texas, and in recent months a civilian engineer with the St. Louis Ordnance District of the Army Ordnance Department, has now been commissioned as lieutenant (jg) in the U.S. Navy, assigned to the Office of Inspector of Naval Material in Cincinnati, Ohio.

DEAN BRADLEY STOUGHTON, past president ⊕, has announced his retirement from active teaching duty as professor of metallurgy at Lehigh University.

ROBERT W. LINDSAY ⊕ has resigned as research metallurgist with the Sealed Power Corp., Muskegon, Mich., to join the faculty of the School of Mineral Industries, Pennsylvania State College, as assistant professor of metallurgy.

E. A. SCHUERER ⊕, formerly wit the National Enameling & Stampin Co. of St. Louis, is now gener superintendent of the Astatic Corp manufacturers of Radar and rad equipment of Youngstown, Ohio.

PAUL FFIELD ⊕, materials eng neer of the Bethlehem Steel Co Shipbuilding Division, Quinc Mass., has relinquished his post take charge as superintendent the newly formed development an research branch of the Centr Technical Department. R. POMFRET, formerly assistant mat rials engineer, now assumes th duties of materials engineer.

GORDON F. IVES has been ap pointed advertising manager Walter Kidde & Co., Inc., replacin C. E. GISCHEL, who has been ap pointed director of product deve opment, in charge of post-wa planning.

ROBERT F. MEHL ⊕, director the Metals Research Laboratory an head of the Department of Meta lurgical Engineering at the Carnegi Institute of Technology, has gon to Brazil to lecture at the Escol Politecnica of the University d Sao Paulo on advanced practice in the application of the scienc of metallurgy in the United States

CASIMER A. MEADOWS ⊕ has bee appointed a welding technician the Des Moines, Iowa, branch of th Solar Aircraft Co.

CHARLES W. WOLFE ⊕, formerl chief engineer for J. D. Lowry consultant on industrial furnac equipment to Railway & Power En gineering Corp., Ltd. of Toronto, i now works engineer for Nationa Tool & Mfg. Co., Kenilworth, N. J

JULIAN E. VORMLAND ⊕, formerl inspector for Lindberg Steel Treat ing Co., is now employed by th Thomas J. Dee Co., Chicago.

MILO J. STUTZMAN ⊕, formerl metallurgist for Yates America Machine Co., Beloit, Wis., has joine the staff of the Engineering Re search Department of University o Michigan.

A. W. DEMMLER ⊕, formerly metallurgical engineer for Vanadium Corp. of America, is now director of metallurgy and research for Campbell, Wyant & Cannon Foundry Co., Muskegon, Mich.

AN INTRICATE DIE-PRESSED ALUMINUM FORGING

by REVERE

Weight: 1¾ lbs.; length: 9"; extreme width: 6"

The intricate die-pressed housing pictured above is really quite a job. It is typical of other difficult die-pressed aluminum forgings that Revere can supply in a wide variety of shapes and weights with a wide range of applications. The aviation industry alone has eagerly availed itself of these strong, close-grained, intricate die-pressed aluminum forgings and will attest their economy and utility. Revere forgings are also available in copper, various copper-base alloys and magnesium.

Revere will be glad to give you technical advice—*without obligation*—on any special problems that you may have in the field of die-pressed forgings. Write Executive Offices.

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Personals

Lewis E. Thelin, formerly with Sargent & Co., New Haven, Conn., is now metallurgist for the Bridgeport Rolling Mills Co., Bridgeport, Conn.

Charles Ellison MacQuigg, dean of engineering at Ohio State University, has been awarded the James Turner Morehead Medal of the International Acetylene Association for "advancing the oxy-acetylene processes through metallurgical research, and for leadership in welding engineering education".

S. Leonard Davidson is now doing research work on protective coatings for National Lead Co. in San Francisco.

A. M. Donze, factory manager of the Timken Roller Bearing Co., Canton, Ohio, has been made vice-president in charge of production.

Russell M. Allen, formerly general manager of sales for Allegheny Ludlum Steel Corp., has been elected vice-president in charge of sales. P. E. Floyd, formerly sales manager of the Chicago district, has been appointed assistant general manager of sales for the Corporation.

Edward A. Kreller, formerly works manager of Detroit Alloy Steel Co., has been appointed manager of the Cast to Shape Department of the Jessop Steel Co. of Washington, Pa. Harry Wilson Jr. has been advanced from works manager to vice-president in charge of operations for Jessop and is succeeded as works manager by Myron M. Eicher.

Carl F. Mayer, president of the Carl Mayer Corp., has been appointed by the War Production Board, Washington, D. C., as a member of the Heat Treating Equipment Advisory Committee.

F. N. Keithley has been appointed district engineer of the Thermit Department, South San Francisco Branch of Metal & Thermit Corp.

Ralph H. Heberling, assistant to the president in charge of manufacturing, Edward Valve & Mfg. Co., Inc., East Chicago, Ind., has been promoted to vice-president.

Paul K. Zimmerman, formerly a student engineer for the National Tube Co., McKeesport, Pa., has been employed as metallurgist for Globe Steel Tubes Co., Milwaukee.

Promoted by Vanadium-Alloys Steel Co.: William Ray Mau from district manager in Chicago to western sales manager with headquarters in Chicago.

Charles W. Olsen, district manager for the Carpenter Steel Co. at Hartford, Conn., has announced his retirement after 49 years of active service with the company. He is succeeded by Wynn F. Rossiter, who has been associated with him on the New England staff of the Carpenter Steel Co.

Alfred S. Kos, formerly assistant factory manager of the Stinson Division of Consolidated Vultee Aircraft Corp., has been appointed general superintendent of the Stout Research Division in Dearborn, Mich.

Triplex Steel Melting in Ford's Foundry*

By A. H. Allen

FORD'S new steel foundry at the Rouge plant is in a new four-story building and is unusually well equipped with conveyors and other labor-saving devices. Flow of material, from cupola charging to pouring the molds, is generally from top to bottom, aided by gravity. Another feature is triplex melting: Cupola to converter to electric furnaces. Capacity is about 10,000 tons finished castings per month. Four molding lines are served: Floor molds for castings up to 1500 lb., centrifugal casting machines, molds served by sandslingers, and small castings molded in jolt-squeezers.

Several 96-in. hot blast cupolas lined to 72 in. are installed at one end of the building. With capacity of 22 tons per hr., two of these melting units are sufficient to keep four bessemer converters blowing, so this is the normal operating procedure. Cupola charge is roughly 25% pig iron, 25% purchased scrap and 50% return scrap. The cupolas tap into 13,000-lb. tilting desulphurizing ladles, oval in shape, set in pairs in front of each cupola so hot metal can flow continuously into one or the other of them, acting as a receiver. Approximately 200 lb. of purite is added per ladle charge, sufficient to reduce sulphur content to 0.05% max.

Converter charges at about 2900° F. are drawn off as needed, skimmed, and taken to acid-lined sideblow converters, ranged in line opposite the cupolas. Time cycle on the bessemer blow is about 28 min. — 4 min. for charging, 20 min. blowing and 4 min. tapping. When the lining is new, the converter will handle about 9000 lb. of iron and as it wears away, this is gradually increased until about 30 or 35 blows the charge grows to around 16,000 lb., whereupon the lining is rebuilt. Blowing period is judged by eye and when the carbon flame has colored to the proper point the charge is poured again into an 8-ton transfer ladle and moved to a slagging station where the heat is skimmed. Analysis of blown metal averages 0.06 to 0.10% carbon, 0.05 to 0.10% manganese, 0.03 to 0.08% silicon, and 0.03 to 0.05% sulphur and phosphorus.

Converter and cupola slag is granulated and conveyed outside to ballast cars. The converters blow into a sheet steel stack equipped with slanting water-

(Continued on page 520)

*Abstracted from "Pours Triplex Steel on Conveyor"; *The Foundry*, September 1943, page 94.

THERE ARE STILL UNDISCOVERED CONTINENTS

COLUMBUS had a definite goal—a westbound sea route to Asia. But what he found was a new continent—a new source of Nature's wealth.

Modern research also has its goals: it, too, is discovering new resources. Starting from the knowns of science, it charts its voyages into the unknown. Behind each voyage is a theory that there is a passageway.

But research doesn't hold stubbornly to its theories. If it finds islands instead of a continent, it accepts them, for it expects the unexpected. It studies their relation to the known lands of science. And on the basis of its increased knowledge, it makes revised plans for progress. In science there is always a continent ahead.

Just what research will disclose can never be forecast. But history has proved that from research flow discoveries of value to mankind. From Bell Telephone Laboratories there has poured a full stream of improvements in the telephone art.

Bell Telephone Laboratories has kept America leading the world in telephony. And its researches have contributed importantly to other arts of communication—to the phonograph and sound-motion pictures, to radio broadcasting and television.

Today, as ever since Pearl Harbor, its efforts in research and design are devoted to the war needs of the nation.

When peace comes, its organized teams of research scientists and engineers will continue to explore and invent and perfect for the improvement of telephony.

BELL TELEPHONE SYSTEM

Triplex Steel Melting in Ford's Foundry

(Continued from page 518)

cooled baffles, to trap oxides from the blow. A hopper at the base of the stack collects this fine material.

Converter metal is skimmed in the ladle and dumped into an electric furnace through an enlarged spout ("charging lip") built on the furnace shell on the side opposite to the tapping spout. A bath of about 10 tons of steel is kept in the electric furnace continually, building up to around 15 tons after Bessemer metal is charged and then receding to 10 tons as steel is tapped out for pouring the molds.

Alloying is usually done in the ladle before transfer to the electric furnaces, the latter being essentially holding furnaces. Analysis of the steel produced for castings requiring high physical properties is 0.30 to 0.35% carbon, 1.10 to 1.30% manganese, 0.15 to 0.40% silicon, 0.40 to 0.50% chromium, and 0.05% max. sulphur and phosphorus.

No phosphorus is removed in either converter or electric, so low phosphorus pig or scrap must be charged into the cupola, a matter that is hoped to be corrected by a basic lined cupola able to carry a dephosphorizing slag, and so utilize high phosphorus scrap.

Finished steel is tapped at about 3000° F. and held in ladle until correct pouring temperature (by pyrometer) is reached. After shake-out the castings are hung on a slow moving conveyor elevator, requiring 5½ hr. to reach the cleaning department on the fourth floor. Continuous normalizing furnaces, 60 ft. long, take three lines of trays through on a 7-hr. cycle. Next to this unit is an even longer double deck quench and draw furnace for steel castings, parts traveling through the high heat zone at the lower level, then are quenched automatically and transferred to the upper level for drawing.

Close by these units is a battery of batch-type homogenizing furnaces, 12x12 ft. in size, for treating armor castings. These furnaces are served by two charging machines whose peel consists of a series of parallel fingers. After the load has been moved forward into the furnace, the fingers lower into slots in the furnace floor, leaving the castings behind. The furnace floor, in fact, is merely a gridiron of beams, made of heat resisting alloys, set close enough together to support the smallest casting to be charged on their upper flanges, yet far enough apart to clear comfortably the fingers on the charging machine.

Electroplating Lea

By Myron B. Diggin

THE USE of electrodeposited le as a substitute for more critic metal coatings has been expande rapidly, and will assume conside able proportions during the remai der of the war. Electrodeposite lead had not formerly found fav with platers partly because of i poor appearance and softness, an partly because of unfamiliarity wi the operating characteristics of th bath.

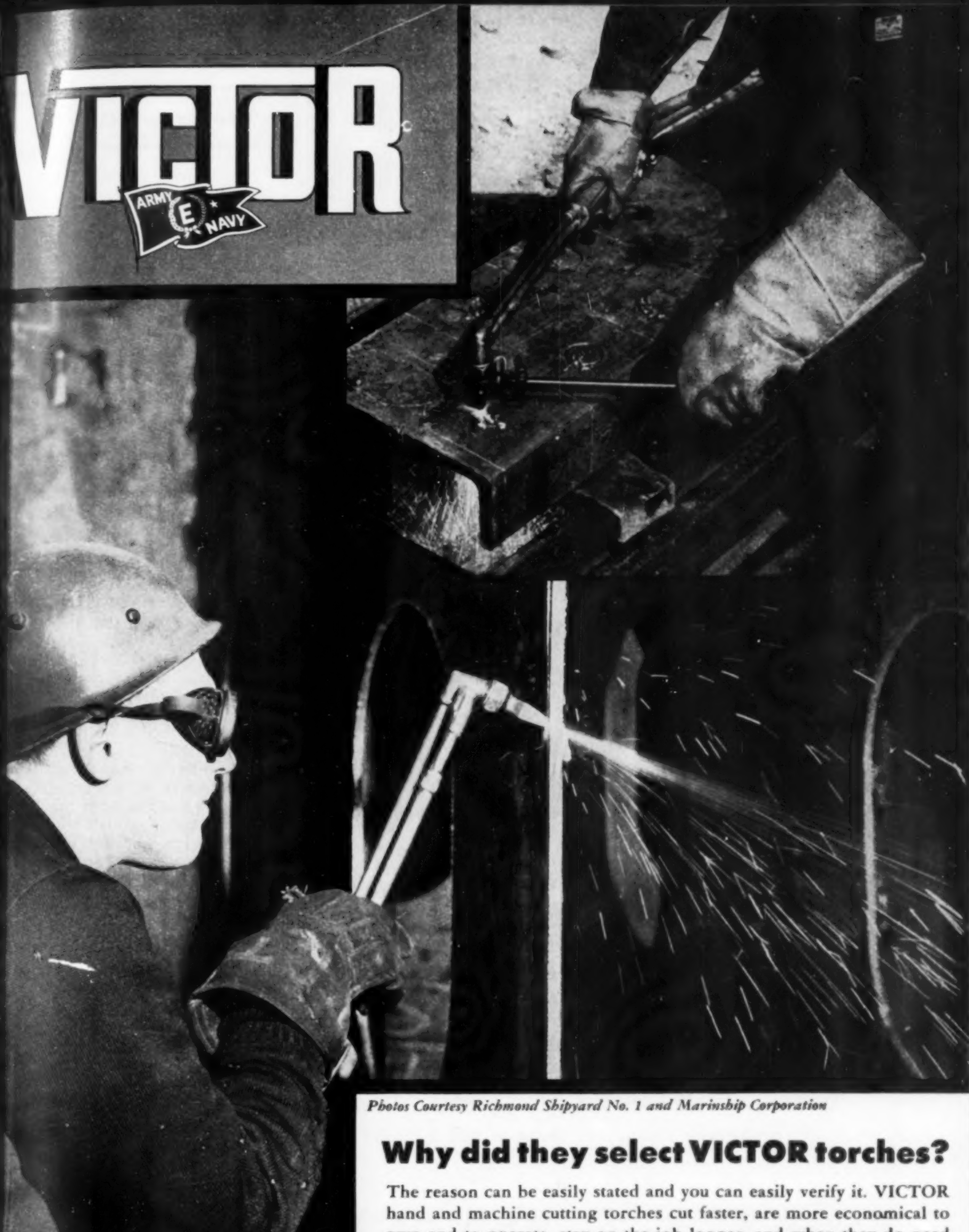
Lead deposits can be used protect iron and steel against co rosion and to obtain a corrosio resistant coating on non-ferrou metals. It is now being substitute for cadmium and zinc coatings fo ordinary conditions of exposure

From its position in the electro chemical series one would assum that lead is cathodic to iron or steel and that therefore lead deposi should accelerate corrosion of th underlying steel if pores or bar areas are present — although to lesser extent than copper. Ther is evidence that under some condi tions of exposure, particularly in marine atmosphere, lead is weakly anodic to steel, and therefore wil exert electrochemical protection although it is not safe to rely upo this in important articles.

Experience with electroplate lead coatings from modern solution has been so limited that a manu facturer or purchaser who contem plates the substitution of lead fo cadmium or zinc is at a loss t know what thickness should b specified as compared with thick ness of cadmium or zinc found t be satisfactory by actual servic Accelerated tests such as salt spra are misleading, and cannot be inte preted in terms of expected li under any conditions of actua atmospheric exposure. Soderber

(Continued on page 524)

*Abstracted from Metal Finish ing, May 1943, p. 418.



Photos Courtesy Richmond Shipyard No. 1 and Marinship Corporation

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Electroplating Lea

(Starts on page 522)

in a recent paper before the Ba more-Washington Branch of American Electrochemical Soci gave an excellent bibliography atmospheric, indoor and salt wa corrosion tests on lead coatin Because of our limited knowle of conditions affecting the depo tion processes in use today, it wo be presumptuous to state that a c tain thickness of electroplated le could be subsituted for, and wo be equivalent to, a definite coati thickness of cadmium or zinc.

For indoor exposure away fr corrosive fumes, where 0.0001 0.0002 in. of cadmium or zinc h been found satisfactory, the wri suggests lead coatings of 0.0002 0.0003 in. For outdoor exposu lead thicknesses of under 0.0005 should not be considered unless t articles are to be lacquered painted. (Incidentally, paint co ings adhere exceptionally well electrodeposited lead.) Prolong protection of surfaces exposed t weather requires 0.001 to 0.002 Similar thicknesses are sugges for indoor exposure in a corros atmosphere.

Severely corrosive conditio may require even heavier coatin — up to 0.003 to 0.004 in. Light burnishing or scratch brushing th lead surfaces after plating wi improve the protective qualitie These suggestions are tentative an must be supplemented by observ tion of parts in service.

Plating Solutions — The le fluoborate bath has survived as th most practical one for commerci use, although the recently intr duced lead sulfamate solution increasing in popularity.

An alkaline lead plating soluti has superior throwing power to th of acid solutions. Another imp tant advantage is that it can be us in unlined steel tanks. Conversi from cadmium and zinc plating alkaline lead plating theref involve no major changes in equi ment or procedure.

The fluoborate solution is ess tially lead fluoborate, Pb(BF stabilized with an excess of fr fluoboric and boric acids. Colloi addition agents are required minimize roughness, to produce finer crystalline structure, and prevent treeing. Baths shou never be operated with a metal co

centration of less than 16 oz. per gal. Where moderately heavy deposits are required or where the utmost in smoothness and throwing power is desired. For building up heavy deposits, the metal concentration can be doubled. The "free" or excess fluoboric acid concentration, as determined by analytical methods, is usually maintained at from 2.5 to 4 oz. per gal., depending upon the metal concentration chosen. It should be emphasized that proportions of basic chemicals must be chosen so that no uncombined hydrofluoric acid is present. The presence of as much as 2 oz. per gal. of uncombined boric acid has been found to have a stabilizing effect upon the bath, in retarding the precipitation of lead fluoride. Smoothest deposits are obtained between 0.02 and 0.04 oz. of glue per gal.

It is of course desirable to control the composition to secure consistent performance.

Operating Conditions — Where electrometric pH apparatus is available, the proper acidity can be controlled by adding fluoboric acid as required to maintain a pH of 1.0 to 1.5.

The control of the colloidal addition agent is more difficult. A small scale test can be made in a jar or Hull cell where the operating conditions can be closely controlled. Inspection of the plated surface at 500 diameters will reveal an excess of glue if the surface contains many dark colored inclusions.

For best operation, cathode current density should be in the range of 5 to 30 amp. per sq.ft. With sufficient agitation, a current density of 80 amp. per sq.ft. has been used for light deposits. The anode current density should be confined to the range of 10 to 25 amp. per sq.ft. in unagitated solutions.

The cathode current efficiency of an uncontaminated lead solution is around 98%. At this efficiency it requires 42 amp. per sq.ft. to deposit 0.0001 in. of lead in one minute. With cathode current density of 15 amp. per sq.ft., it will require at least 2.8 min. to deposit a thickness of 0.0001 in., or 28 min. for 0.001 in.

The voltage required for still plating will depend upon the anode-cathode relationship, the solution composition and the current density employed. At 5 to 10 amp. per sq.ft., 1 to 1.5 volts are sufficient; at 10 to 20 amp. per sq.ft., 1.25 to 2.0 volts suffice. Above 20 amp. per sq.ft. the voltage

(Continued on page 526)

Electroplating Lead

(Starts on page 522)

required may exceed 2 volts. F barrel plating, a full 6 volts is sat factory.

The operating temperature the fluoborate bath is not critic Agitation is not required wh plating at moderate current den ties. Above 30 amp. per sq.ft. cathode rocker or submerged sol tion agitator minimizes treeing sharp corners or protruding area

Anodes of the purest chemic lead are best. Tanks construct of steel with either rubber or sy thetic linings give excellent servic Plating cylinders should be fabr cated from suitable laminated pla tics or hard rubber.

The same care is required preparing surfaces for lead platin as for nickel plating. In genera anodic electrocleaning, rinsin acid dipping or pickling in eith hydrochloric or sulphuric acids fo lowed by thorough rinsing is us ally a sufficient treatment prior lead plating. Castings should well cleaned by sand or shotblas ing. A copper strike of abo 0.00002 in. is often beneficial securing good coverage an improving adhesion.

If a sulphuric acid pickle is use in the cleaning cycle, a doubl water rinse is recommended befor the work is transferred to the lea bath. In areas where the wat supply is high in sulphates, a di tilled water rinse preceding th plating tank will help keep th solution clean. It is advisable t use distilled water to replace evap oration losses. Stainless steel filte have been found serviceable whe the clear solution can be decante from the sludge.

Health Aspects — There ar hazards involved in handling co centrated hydrofluoric acid an dry lead salts. Because of tha many manufacturers prefer to pu chase prepared lead solutions concentrated form which are sin ply diluted with water to form working solution. There are se eral excellent concentrates avai able on the market.

Since lead is a cumulative po son, personal cleanliness should b emphasized, so there may be n possibility of lead salts getting int the mouth. In general, the sam recommendations that have bee made regarding cadmium coating in respect to their use around food stuffs should be followed.

WHAT'S NEW

IN MANUFACTURERS' LITERATURE

METAL WORKING • FABRICATION

Wall charts and manual sheets by Firth-Sterling Steel Co. make easy the selection of color-branded sintered carbides for cutting tools. Bulletin 391.

Marvel metal cutting saws. Armstrong-Blum Mfg. Co. Bulletin 395.

16-page booklet features 22 short stories of how proper cutting fluids have solved production problems. D. A. Stuart Oil Co. Bulletin 403.

Powdered metal presses. Kux Machine Co. Bulletin 1.

Forging presses. Ajax Mfg. Co. Bulletin 2.

Horizontal extrusion presses. Hydropress, Inc. Bulletin 3.

36-page pictorial story of the Cecostamp. Cambersburg Engineering Co. Bulletin 4.

Cutting Oils. Cities Service Oil Co. Bulletin 5.

Presses for Powder Metallurgy. F. J. Stokes Machine Co. Bulletin 7.

Information and data on straightening press. Anderson Bros. Mfg. Co. Bulletin 10.

Properties and uses of cutting oils. Gulf Oil Corp. Bulletin 8.

Surface coated abrasive belts. Minnesota Mining & Mfg. Co. Bulletin 12.

Presses for the metal working and process industries. Hydraulic Press Mfg. Co. Bulletin 20.

Savings in oils, tool bits, grinding wheels. Sparkler Mfg. Co. Bulletin 15.

New catalog illustrates standard, non-standard, and special tools. Kennametal, Inc. Bulletin 250.

Mounted wheels, Handee and Hi-Power tools. Chicago Wheel & Mfg. Co. Bulletin 21.

20-page booklet on cutting fluids. Tide Water Associated Oil Co. Bulletin 252.

Air tools in steel mills and foundries are pictured in new booklet by Ingersoll-Rand. Bulletin 255.

Big, comprehensive catalog illustrates line of power presses offered by Minster Machine Co. Bulletin 320.

New leaflet describes the Doall band filing machine. Continental Machines, Inc. Bulletin 430.

Complete and valuable study "Machining of Metals", includin chip formation, is offered by N tional Refining Co. Bulletin 335.

Lubricoolant, a new type of co ant said to prolong tool life on m als from chrome-molybdenum st to aluminum alloys, is described new leaflet issued by the DuBois Bulletin 408.

Complete summary of new Do tools is presented in new booklet sued by Doall Service Co. Bulle 432.

Safe-T tongs and their use in m terials handling are described new booklet by Heppenstall Bulletin 434.

63-page pocket booklet shows u ful tables of weights and measu used in the metal industry. Me Machine Co. Bulletin 441.

Practical data sheet describes c ting and grinding compound. I versey Corp. Bulletin 447.

FERROUS METALS

Republic Steel Corp.'s second e tion of National Emergency Ste tells you all about these new stee Bulletin 345.

Aircraft steels, bearing steels. I tary Electric Steel Co. Bulletin 4

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Other Manufacturers' Literature
Listed on Pages 546, 548, 550, 554, 5
558, 560, 562, 564, 566, 568, 572 and 5

Metal Progress 7301 Euclid Ave., Cleveland 3, Ohio — March, 194

Send me the Literature I have indicated below.

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20	59	91	119	150	177	206	281	324	358	384	412	435	455
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BRAZING
TUNGSTEN-CARBIDE ON CUTTING TOOLS

THIS is another Hoskins Brazing Furnace, in the plant of the Wesson Company, makers of carbide-tipped tools, such as shown in the panel. No production figures are available, but the user says the furnace turns out a lot of work, of first class quality, and at a reasonable cost. The furnace is well powered and has a fast recovery rate. Economical in consumption of power, and hydrogen, which is automatically controlled. It takes up little room, and is used on a wide variety of brazing operations. No skill required to operate it. If interested, ask for Catalog 58.

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WHAT'S NEW

IN MANUFACTURERS' LITERATU

Page after page of useful techni data and reference tables on t steels. Latrobe Electric Steel Bulletin 367.

Steel Data Sheets. Wheelock, Lo joy & Co. Bulletin 25.

Molybdenum wrought stee Molybdenum Corp. of America. B letin 26.

Free Machining Steels. Mona Steel Co. Bulletin 30.

Chemical analyses, shapes a sizes of Joslyn stainless steel pr ucts. Joslyn Mfg. and Supply Bulletin 297.

Tool Steels. Bethlehem Steel Bulletin 31.

Enameling iron sheets. Inla Steel Co. Bulletin 33.

Loose-leaf reference book on m lybdenum steels. Climax Molyb num Co. Bulletin 35.

Aircraft Alloy Steels. Joseph T Ryerson & Son, Inc. Bulletin 40

Kinite alloy tool steel bar stock. Boker & Co., Inc. Bulletin 258.

New Catalog C makes it easy to International Nickel Co. literature it presents brief description and dex to a wide variety of bookle Bulletin 305.

"Graphitic Booklet" gives complet information on new, free-machini long-wearing steel. Steel & Tu Div., Timken Roller Bearing C Bulletin 307.

Spark Testing Guide—a 21" x 3 wall chart—is useful in segregati tool steel scrap, unscrambling mix stocks and checking identity of to steel before heat treatment. Carpe ter Steel Co. Bulletin 312.

HWD hot work die steel and Ste ling stainless steels are described four new leaflets by Firth-Sterli Steel Co. Bulletin 323.

Engineering and comparative in formation on porcelain enamel iron is presented in new illustrat booklet by American Rolling Mill C Bulletin 376.

New booklet gives full informati on N-A-X high tensile and N-A 9100 Series of alloy steels. Gre Lakes Steel Corp. Bulletin 328.

Attractive new catalog describ the line of steel offered by Peni sular Steel Co. Bulletin 337.

Use Handy Coupon on Page 544 for Ordering Helpful Literature. Other Manufacturers' Literature Listed on Pages 544, 548, 550, 554, 5 558, 560, 562, 564, 566, 568, 572 and 57

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WHAT'S NEW
IN MANUFACTURERS' LITERATURE

Spindle speed calculator is handy chart to figure machining rates on bar steels. Bliss & Laughlin, Inc. Bulletin 333.

64-page booklet describes the welding of stainless steels. Allegheny Ludlum Steel Corp. Bulletin 384.

Technical data booklet on Mo-Max steels is offered by Cleveland Twist Drill Co. Bulletin 435.

84-page tool and die steel handbook just issued by Ziv Steel & Wire Co. is a helpful guide to selection, treatment and use of these important steels. Bulletin 440.

32-page booklet which pictorially and textually amounts to a scientific treatise on two carbon steels—Speed Case and Speed Treat—has been issued by W. J. Holliday & Co. Bulletin 450.

Fitzsimons Co. issues interesting leaflet on speed case and speed treat steels. Bulletin 452.

NON-FERROUS METALS

80-page pipe and tube bending handbook has been issued by Copper & Brass Research Assn. Bulletin 399.

Platinum Metal Catalysts. Baker & Co., Inc. Bulletin 41.

Die casting equipment. Lester-Phoenix, Inc. Bulletin 42.

Copper Alloys. American Brass Co. Bulletin 45.

Handy & Harman has issued a revised edition of their general catalog on Sil-Fos and Easy-Flo brazing alloys. Bulletin 43.

Brass and bronze castings. Hammond Brass Works. Bulletin 48.

Reference on properties of lead. St. Joseph Lead Co. Bulletin 49.

6th edition of Revere Weights and Data Handbook. Revere Copper and Brass, Inc. Bulletin 296.

80-page Duronze Manual, well indexed for reference, presents data on high strength silicon bronzes. Bridgeport Brass Co. Bulletin 52.

Rare metals, alloys and ores. Foote Mineral Co. Bulletin 56.

Brazing Booklet. Westinghouse Elec. & Mfg. Co. Bulletin 57.

Dowmetal data book. Dow Chemical Co. Bulletin 51.

Two new Ampco Metal data sheets discuss forging Ampco to improve physical characteristics and use of Ampco for non-scratching feed fingers. Bulletin 314.

20-page book shows each step i production of brass and aluminu castings by Manufacturers Bra Foundry Co. Bulletin 414.

Aluminum and its importance t product designers is the title of 2 page booklet issued by Reynold Aluminum Co. Bulletin 418.

"Designing with Magnesium" is t tle of new book offered by America Magnesium Corp. Bulletin 433.

WELDING

Welding Stainless. Page Steel & Wire Div., American Chain & Cabl Co., Inc. Bulletin 59.

Oxy-acetylene welding and cutting Linde Air Products Co. Bulletin 62

Chart explains how to select prope flux for every welding, brazing an soldering job. Krembs & Co. Bul letin 60.

Welding and brazing of aluminum a new data book issued by Alumi num Co. of America. Bulletin 66.

Data book facts on spot, seam an flash welding ferrous and non-fer rous metals and alloys. P. R. Mal lory & Co., Inc. Bulletin 65.

Shield Arc electrodes. McKay Co Bulletin 67.

New advances in arc welding equipment design. Harnischfeger Corp. Bulletin 68.

Nu-Braze No. 4, an improved silve brazing alloy. Sherman & Co. Bulle tin 288.

New 12-page booklet tells how t fabricate fittings for welded piping by means of flame-cutting and weld ing. Air Reduction Co. Bulletin 234

Atomic-hydrogen arc welding, it application and use, is described b General Electric Co. in new Bulleti 241.

32-page catalog describes line o welding equipment offered by Vic tor Equipment Co. Bulletin 245.

Advantages and physical charac teristics of "No-Wear", a hard-facing material. Callite Tungsten Corp. Bul letin 251.

New 500 lb. capacity welding po sitioner for light welding jobs is de scribed by Ransome Machinery Co Bulletin 313.

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Other Manufacturers' Literature Listed on Pages 544, 546, 550, 554, 556, 558, 560, 562, 564, 566, 568, 572 and 574.

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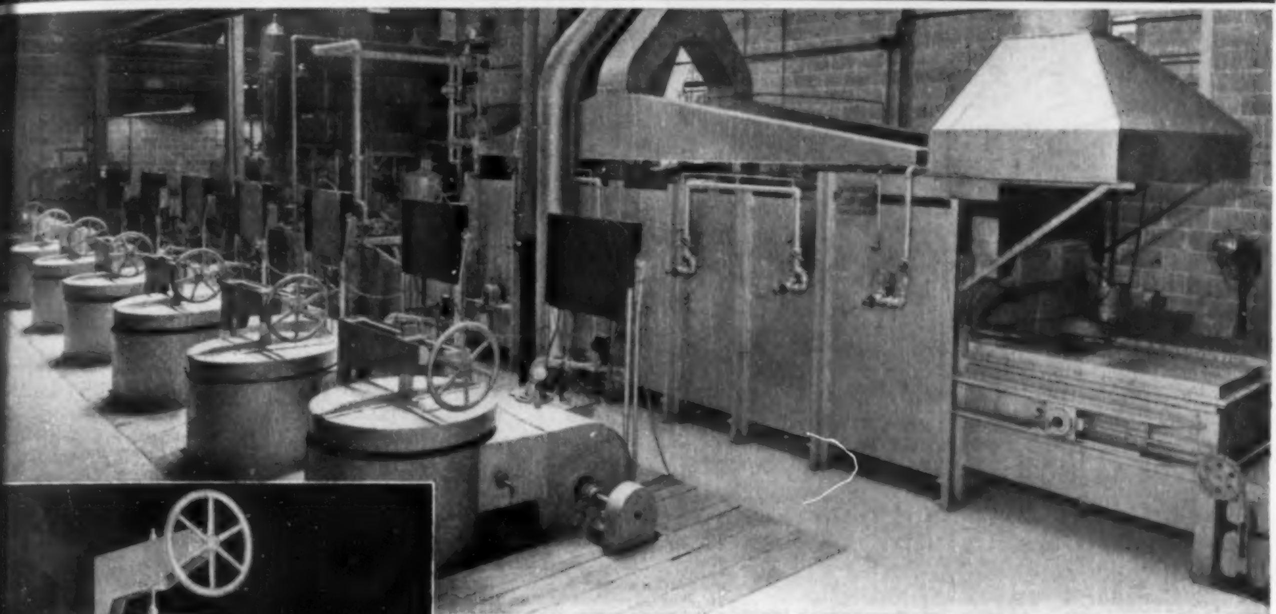

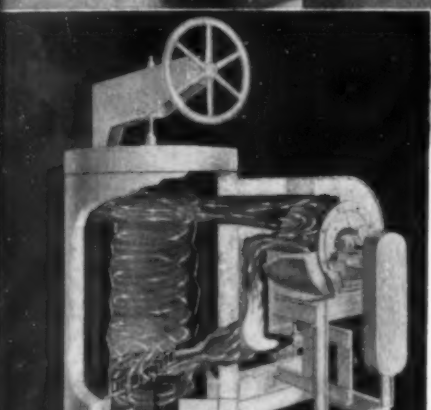

The above cut-away view shows operation of the Standard Stewart Basket Type Recirculating Air Draw Furnace. Note the unrestricted and uniform air flow recirculation to provide thorough, even heat distribution throughout the load. Ample fan capacity and powerful fan motors assure maximum uniformity and production. The flexibility and wide temperature range are two basic reasons why Stewart Recirculating Furnaces are turning in such good performance records on a wide variety of jobs.

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The above installation is typical of many STEWART wartime installations that are well suited, because of versatility and wide heat treating range, to peacetime operations.

The conveyor furnace on the right is designed to heat for hardening with automatic conveyor quench, but is also adaptable to normalizing, annealing or similar operations in the temperature range of 1350° to 1600° F. With this versatility all ordinary heat treating operations for small forgings, tools, machine parts, etc., can be carried out with minimum manpower, fully controlled as to temperature and cycle.

The Basket type recirculating furnaces shown on the left permit segregation of products for varied tempering cycles. Drop forgings, die castings, sand castings, stampings, or anything else small enough to be most conveniently handled in batches, can be heated quickly and uniformly in this furnace. The ease with which a whole basket load can be placed in or removed from the heating chamber gives these furnaces a great daily output. For example, a furnace with a 30 inch diameter by 36 inches deep basket can turn out over 20,000 lbs. of steel per day.

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WHAT'S NEW

IN MANUFACTURERS' LITERATURE

Two new hard-facing alloys furnished as welding rods for application by Oxy-Acetylene process are described by the Stoody Co. in Bulletin 325.

New line of welding positioners with dual capacity are described in new booklet by Harnischfeger Corp. Bulletin 350.

Vest pocket guide to correct welding practices is offered by Hobart Brothers Co. Bulletin 351.

Comparable arc welding electrodes for stainless are shown in chart issued by Alloy Rods Co. Bulletin 353.

Attractive, new booklet describes electric resistance welder for aluminum and its alloys. Sciaky Corp. Bulletin 358.

Helpful electrode color chart is offered by the Arcos Corp. Bulletin 374.

Arc welding inspection chart, designed so that operators can tell at a glance whether welds are being properly made, has been issued by the Lincoln Electric Co. Bulletin 411.

"The Eutectic Welder" is title of monthly publication devoted to welding news issued by Eutectic Welding Alloys Co. Bulletin 412.

Many uses and advantages of Colmonoy hard facing alloys and overlay metals are illustrated in new 8 page folder issued by Wall-Colmonoy Corp. Bulletin 415.

New Phos-Copper booklet explains ways to braze, design and applications. Westinghouse. Bulletin 455.

TESTING & INSPECTION

Picker X-Ray Corp. has file of four helpful booklets showing line of X-ray equipment and supplies. Bulletin 402.

Bibliography of more than 700 papers dealing with the polarographic method of metal analysis and a booklet discussing this equipment is offered by E. H. Sargent & Co. Bulletin 338.

Various methods and specific applications of the measurement of case depth are described in illustrated pamphlet offered by Allen B. DuMont Laboratories, Inc. Bulletin 339.

Metallurgical polishing equipment offered by Precision Scientific Corp. is described in illustrated booklet. Bulletin 359.

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WHAT'S NEW

IN MANUFACTURERS' LITERATURE

SR-4 strain gage and illustrations of its many uses. Baldwin Southwark. Bulletin 70.

New book contains wealth of practical, usable information on industrial inspection by x-ray. Westinghouse Electric & Mfg. Co. Bulletin 71.

X-Ray Diffraction Unit. General Electric X-ray Corp. Bulletin 72.

Electric heaters and controls for industrial and laboratory. American instrument Co. Bulletin 75.

Inspection of non-magnetic metals with the new Zyglo method. Magnaflux Corp. Bulletin 78.

Industrial radiography with radium. Canadian Radium & Uranium Corp. Bulletin 79.

Gage blocks, comparators, projectors. George Scherr Co. Bulletin 83.

Portable Brinell hardness tester and folding Brinell microscope. Andrew King. Bulletin 85.

Universal testing machines and typical uses. Riehle Testing Machine Div., American Machine and Metals, Inc. Bulletin 86.

Dillon tensile tester and the Dillon dynamometer. W. C. Dillon & Co. Bulletin 91.

Optical Aids. Bausch & Lomb Optical Co. Bulletin 94.

Coleman universal spectrophotometer. Wilkens-Anderson Co. Bulletin 95.

Metallographic polishing powder. Conrad Wolff. Bulletin 96.

Metallurgical Equipment. Adolph I. Buehler. Bulletin 97.

Hardness testing equipment. Wilson Mechanical Instrument Co., Inc. Bulletin 98.

Attractive, illustrated booklet describes Clark Instrument's precision hardness tester. Bulletin 318.

"Radiography of Materials" is title of new 96-page book on industrial radiography. Eastman Kodak Co. Bulletin 331.

Stresscoat, a method of analyzing distribution, direction and value of local strains. Magnaflux Corp. Bulletin 301.

Two new folders describe Searchray 80, new self-contained X-ray unit of North American Philips Co. Bulletin 377.

High intensity industrial illuminator is illustrated and described in new leaflet by Kelley-Koett Mfg. Co. Bulletin 406.

30th Anniversary Catalog shows the special metallurgical equipment offered by Claud S. Gordon Co. Bulletin 410.

Laboratory and industrial pH meters are described and explained in leaflet issued by Beckman Instruments Division. Bulletin 422.

8-page illustrated leaflet describes line of industrial instruments offered by the Brush Development Co. Bulletin 428.

"Spectrographer's News Letter" is title of interesting new publication by Harry W. Dietert Co. Bulletin 451.

TEMPERATURE CONTROL

New 29-page catalog — Micromax Electric Control — has just been issued by Leeds & Northrup Co. Bulletin 76.

Potentiometer temperature indicators. Foxboro Co. Bulletin 82.

Micro-Optical Pyrometers. Pyrometer Instrument Co. Bulletin 89.

Pyrometer control of high speed salt baths is described in new booklet by Brown Instrument Co. Bulletin 324.

Industrial thermocouples. Arklay S. Richards Co. Bulletin 93.

Pyrometer Controller. Illinois Testing Laboratories, Inc. Bulletin 84.

New leaflet describes valve operator of industrial operation of valves, dampers and other control devices. Automatic Temperature Control Co. Bulletin 381.

New Pyrometer Accessory Manual gives engineering data on selection and installation of thermocouples. The Bristol Co. Bulletin 421.

16-page booklet describes and illustrates Wheelco Instrument Co.'s line of measuring and control instruments. Bulletin 425.

HEATING • HEAT TREATMENT

Equipment for determining the quantity of sodium cyanide in molten cyanide mixtures used in heat treatment is described in new bulletin by the Kocour Co. Bulletin 394.

Use Handy Coupon on Page 544 for Ordering Helpful Literature.
Other Manufacturers' Literature Listed on Pages 544, 546, 548, 550, 556, 558, 560, 562, 564, 566, 568, 572 and 574.

Industry finds wide variety of uses for • •

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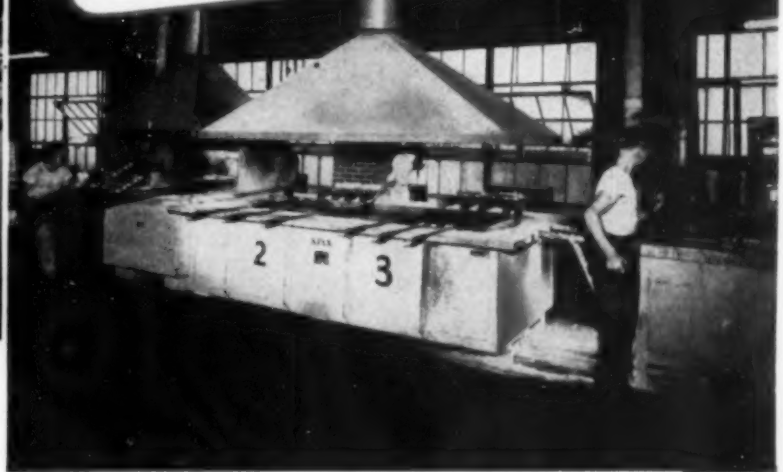

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WHAT'S NEW

IN MANUFACTURERS' LITERATUR

24-page technical data and opera ing manual covering the Deepfree low temperature industrial chillin machines has been issued by Deej freeze Div., Motor Products Cor Bulletin 398.

36-page catalog illustrates Kol Hold line of thermal, sub-zero an stratosphere processing and testin machines. Kold-Hold Mfg. Co. Bull tin 99.

Induction heating. Induction Hea ing Corp. Bulletin 103.

Internally heated salt bath furnace and pots. Upton Electric Furnac Div. Bulletin 102.

Easy-selection charts on gas burning equipment. National Ma chine Works. Bulletin 105.

8-page pictorial bulletin describe the heat treating service of Conti nental Industrial Engineers, Inc. Bul letin 107.

Electric Furnaces. Ajax Electro thermic Corp. Bulletin 106.

Lithco, the chemically-neutral hea treating process, and Lithcarb, th process for fast, bright gas-carburiz ing. Lithium Corp. Bulletin 101.

Furnaces for heat treatment of alu minum, magnesium and their alloys Lindberg Engineering Co. Bulleti 271.

Gas, oil and electric heat treatin and carburizing furnaces. Holcrof & Co. Bulletin 114.

Industrial furnaces, equipment fo bright annealing stainless steels an ammonia dissociation equipmen Drever Co. Bulletin 115.

Industrial ovens, rod bakers, weld ing rod ovens, furnaces. Carl-Maye Corp. Bulletin 116.

Full muffle and other heat treatin furnaces described in catalog b Charles A. Hones, Inc. Bulletin 117

Non-metallic Electric Heating Ele ments. Globar Div., Carborundun Co. Bulletin 119.

56-page vest pocket data book on heat treating practices and proce dures. Chicago Flexible Shaft Co Bulletin 118.

24-page catalog describes gas, oi and electric Holden heat treating po furnaces, and baths. A. F. Holden Co Bulletin 120.

Use Handy Coupon on Page 544 for Ordering Helpful Literature.
Other Manufacturers' Literature Listed on Pages 544, 546, 548, 550, 554, 558, 560, 562, 564, 566, 568, 572 and 574

WHAT'S NEW

IN MANUFACTURERS' LITERATUR

Control **of temperatures of quencling baths. Niagara Blower Co. Buletin 122.**

Molten Salt Baths. **E. I. DuPo de Nemours & Co., Inc., Electrochenicals Department. Bulletin 123.**

Handling **cylinder anhydrous a monia for metal treaters. Armo Ammonia Works. Bulletin 128.**

Industrial Furnaces. **W. S. Roc well Co. Bulletin 133.**

Certain Curtain Furnaces. **C. Hayes, Inc. Bulletin 134.**

Air-Oil Ratiotrol **for proportionin flow of fuel oil and air to oil burner North American Mfg. Co. Bulleti 135.**

Two new bulletins **on vertical ca burizers and on carbonia finis American Gas Furnace Co. Bull tin 139.**

Van Norman **induction heatin units. Van Norman Machine Tool C Bulletin 144.**

Gas-air premix machine. **Eclips Fuel Engineering Co. Bulletin 13**

Controlled atmosphere furnac **Delaware Tool Steel Corp. Bulleti 141.**

Dual-Action quenching oil. **Gu Oil Co. Bulletin 132.**

Furnaces. **Tate-Jones Co. Bulleti 142.**

Industrial Carburetors. **C. M. Ken Mfg. Co. Bulletin 143.**

Heat treating, **brazing and mel ing of ferrous and non-ferrous me als. Lepel High Frequency Labor tories, Inc. Bulletin 147.**

Vertical Furnace. **Sentry Co. Bu letin 148.**

Conveyor Furnaces. **Electric Fu nace Co. Bulletin 149.**

High and low temperature **dire fired furnaces. R-S Products Cor Bulletin 146.**

New Electric Furnace. **America Electric Furnace Co. Bulletin 15**

Electric Furnaces **for laborato and production heat treatment. Ho kins Mfg. Co. Bulletin 152.**

Flame-type **mouth and taper a nealing machine for steel cartrid cases. Morrison Engineering Cor Bulletin 154.**

Use Handy Coupon on Page 544 for Ordering Helpful Literature. Other Manufacturers' Literature Listed on Pages 544, 546, 548, 550, 55 556, 560, 562, 564, 566, 568, 572 and 57

WHAT'S NEW
IN MANUFACTURERS' LITERATURE

Dehumidifier. Pittsburgh Lectrodryer Corp. Bulletin 155.

No-Carb, a liquid paint for prevention of carburization or decarburization. Park Chemical Co. Bulletin 156.

16-page engineering and data booklet on proportioning oil burners. Hauck Mfg. Co. Bulletin 160.

Pictorial bulletin describes furnaces for heat treating, normalizing, annealing, forging. Vulcan Corp. Bulletin 161.

High Temperature Fans. Michiana Products Corp. Bulletin 158.

Protective combusted atmospheres in Hevi Duty Electric Co. furnaces are discussed in 12-page Bulletin 316.

Turbo-Compressor data book shows how to calculate compressed air systems for a dozen different applications. Spencer Turbine Co. Bulletin 329.

Catalog of heat treating materials. Heatbath Corp. Bulletin 322.

Standardized sizes of semi-muffle and pot-type furnaces are described and pictured in new leaflet by Dempsey Industrial Furnace Corp. Bulletin 354.

Use of pulverized coal in the metallurgical industries, equipment and designs, are described by Amsler-Morton Co. in Bulletin 361.

Illustrated bulletin on stress-relieving, car-type furnaces. Radiant Combustion. Bulletin 375.

Furnaces for heat treating tools, dies and parts are described in new leaflet by Despatch Oven Co. Bulletin 362.

Rapid oil coolers and heat transfer equipment are described in new catalog issued by Bell & Gossett Co. Bulletin 365.

New book "Hardness" describes and evaluates hardness research of noted pioneers, methods of testing and testing instruments. Nitralloy Corp. Bulletin 366.

New booklet describes uniform case hardening up to .150" with controlled carburizing baths. American Cyanamid & Chemical Corp. Bulletin 372.

82-page catalog describes in detail General Electric heat treat furnaces. Bulletin 380.

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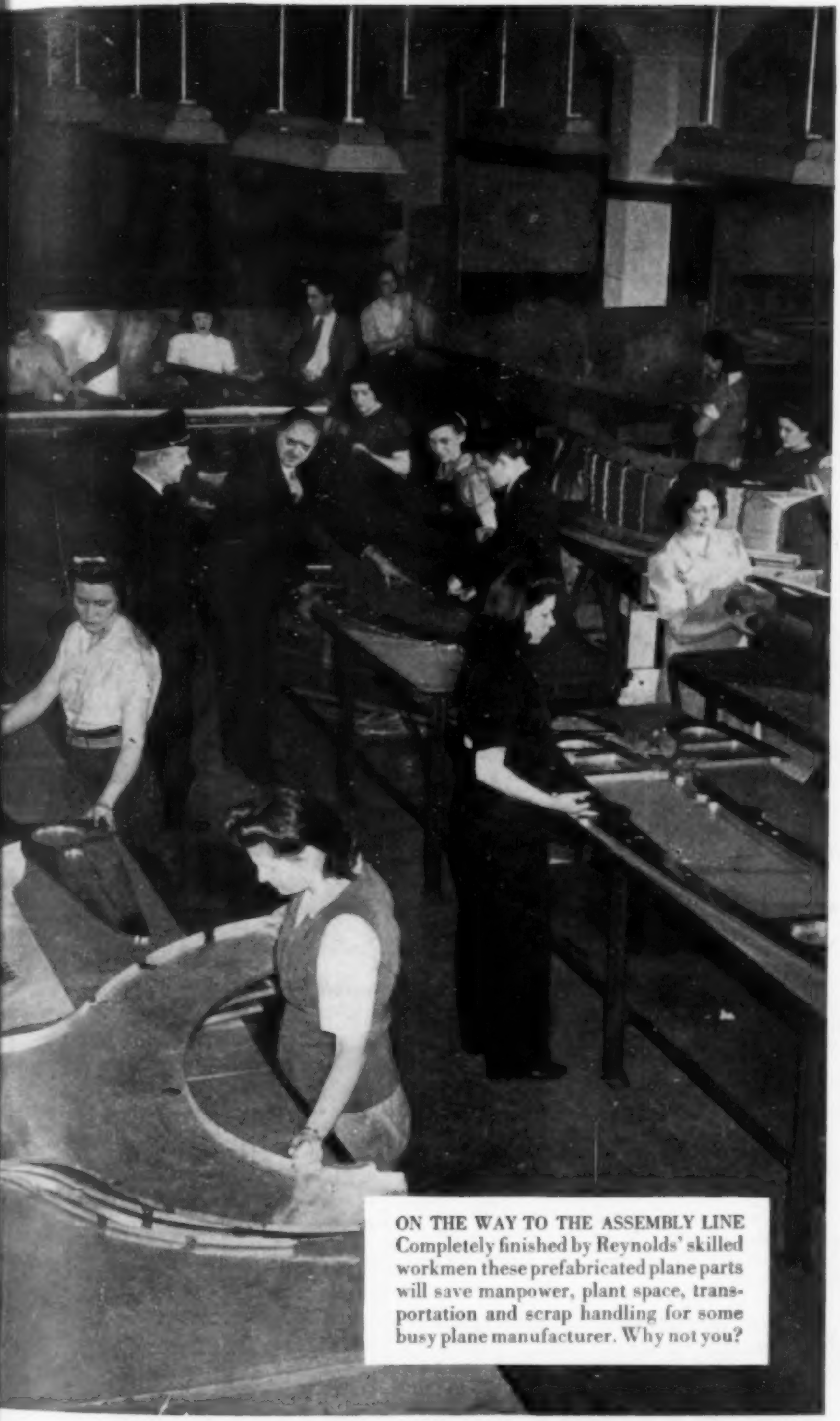

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Completely finished by Reynolds' skilled workmen these prefabricated plane parts will save manpower, plant space, transportation and scrap handling for some busy plane manufacturer. Why not you?

by Prefabricated Plane Parts Service . . . Pioneered by REYNOLDS

Here's one answer to your manpower shortage. An answer that's already saving thousands of precious man-hours of airplane labor for every leading manufacturer of combat planes.

Under this plan, pioneered by Reynolds only 3 years ago, completely finished parts come to your production lines ready for immediate assembly. No longer is it necessary to tie up valuable plant space with large stocks of aluminum sheet or die-cutting and forming machines.

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The Reynolds prefabricated plane parts service also does away with scrap handling. Aluminum scrap, which averages 30% of every sheet, is immediately re-rolled into prime sheet, then prefabricated into more new parts, practically overnight.

It is this kind of progressive thinking and co-operative planning that has resulted in an organization which now operates 40 plants in 14 states, and continues to grow by leaps and bounds. For Reynolds men are not satisfied to have been the first to supply finished plane parts from aluminum sheet. They have given themselves the continuous job of finding new ways to make aluminum better . . . easier and cheaper to use.

That's why you'll find Reynolds' resources, equipment and engineering skill can be of assistance in helping you with your aluminum problems, *no matter what they may be.* Reynolds Metals Company, Aluminum and Parts Divisions, Louisville, Ky.

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INGOT • SHEET • EXTRUSIONS • WIRE • ROD • FORGINGS • TUBING • FOIL • POWDER

WHAT'S NEW

IN MANUFACTURERS' LITERATURE

Four basic heat treating atmospheres are described in new booklet by Westinghouse. Bulletin 383.

War Production Data — 30 pages of useful information on metal working, heat treating and other metal producing operations just issued by E. F. Houghton & Co. Bulletin 387.

Laboratory and tool room furnace. Mahr Mfg. Co. in new Bulletin 327.

Heat Treating Topics" is title of new bulletin of special interest to heat treaters, issued by Rex & Erb. Bulletin 424.

New leaflet pictures many applications of selective heating with salt bath furnaces. Ajax Electric Co. Bulletin 429.

Interesting, practical booklet takes a look at the future of the heat treating furnace. Surface Combustion. Bulletin 442.

Many applications of induction hardening are described in new 32-page booklet issued by Ohio Crankshaft Co. Bulletin 444.

Vapocarb-Hump method for heat treatment of steel is the title of a newly-revised catalog issued by Leeds & Northrup. Bulletin 453.

REFRACTORIES & INSULATION

Insulating firebrick. Babcock & Wilcox Co. Bulletin 162.

Heavy Duty Refractories. Norton Co. Bulletin 164.

Cromox, new protective refractory coating material for prolonging life of firebrick, insulating firebrick, and castable refractories. Federal Refractories Corp. Bulletin 163.

Super Refractories catalog. Carborundum Co. Bulletin 165.

Conductivity and heat transfer charts. Johns-Manville. Bulletin 167.

D-E insulating materials and their application are described in new data booklet by Armstrong Cork Co. Bulletin 208.

Zircon refractories in aluminum open hearth furnaces. Chas. Taylor Sons Co. Bulletin 347.

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Accuracy that Counts on all Fronts

At first glance there would seem to be little relationship between an intricate, ten-foot long height finder and a microscope objective with lenses of less than one millimeter in radius. Yet both are the products of the same eyes, the same facilities, the same standards of accuracy, the same experience. Both are aiding in America's war effort. Both are products of Bausch & Lomb.

The lens computing and grinding skills that for years have produced the minute, exceedingly accurate lens components of the microscope objective are today also being employed in the production of height-finders and gunfire control instruments that are helping America's armed forces to win an earlier Victory.

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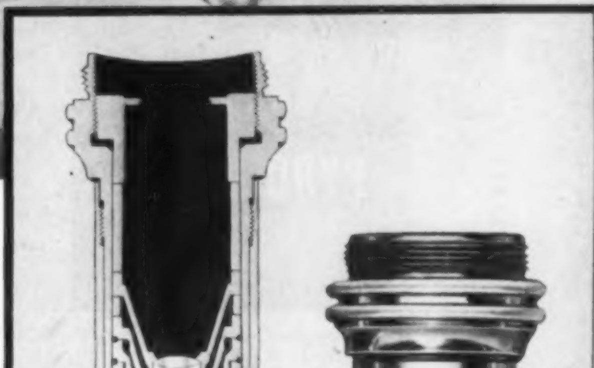

Bausch & Lomb Oil Immersion Objective—97X-N.A. 1.25—1¾ x Actual Size.

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WHAT'S NEW

IN MANUFACTURERS' LITERATURE

Steel Plant Cement for hot or cold patching of soaking pits, open hearths, electric furnaces, forging furnaces and reheating furnaces is described in new folder by Electro Refractories & Alloys Corp. Bulletin 407.

695, a highly refractory, strong magnesia plastic for taphole construction and hot repairs. Basic Refractories, Inc. Bulletin 443.

FINISHING • PLATING • CLEANING

Automatic and semi-automatic plating equipment for a variety of processes and products are illustrated in 40-page booklet issued by Frederic B. Stevens, Inc. Bulletin 397.

Roto-Finish equipment for deburring, buffing, polishing and coloring. Sturgis Products Co. Bulletin 170.

A protective, deep black finish to steel. Heatbath Corp. Bulletin 171.

Alvey Ferguson Co. shows how various product washing problems were solved. Bulletin 172.

Motor-Generators for electroplating and other electrolytic processes. Columbia Electric Mfg. Co. Bulletin 173.

Pickling. Wm. M. Parkin Co. Bulletin 174.

Detrex metal cleaning machines, metal cleaning chemicals and processing equipment. Detrex Corporation. Bulletin 175.

Electrochemical Descaling. Bullard-Dunn Process Div., Bullard Co. Bulletin 212.

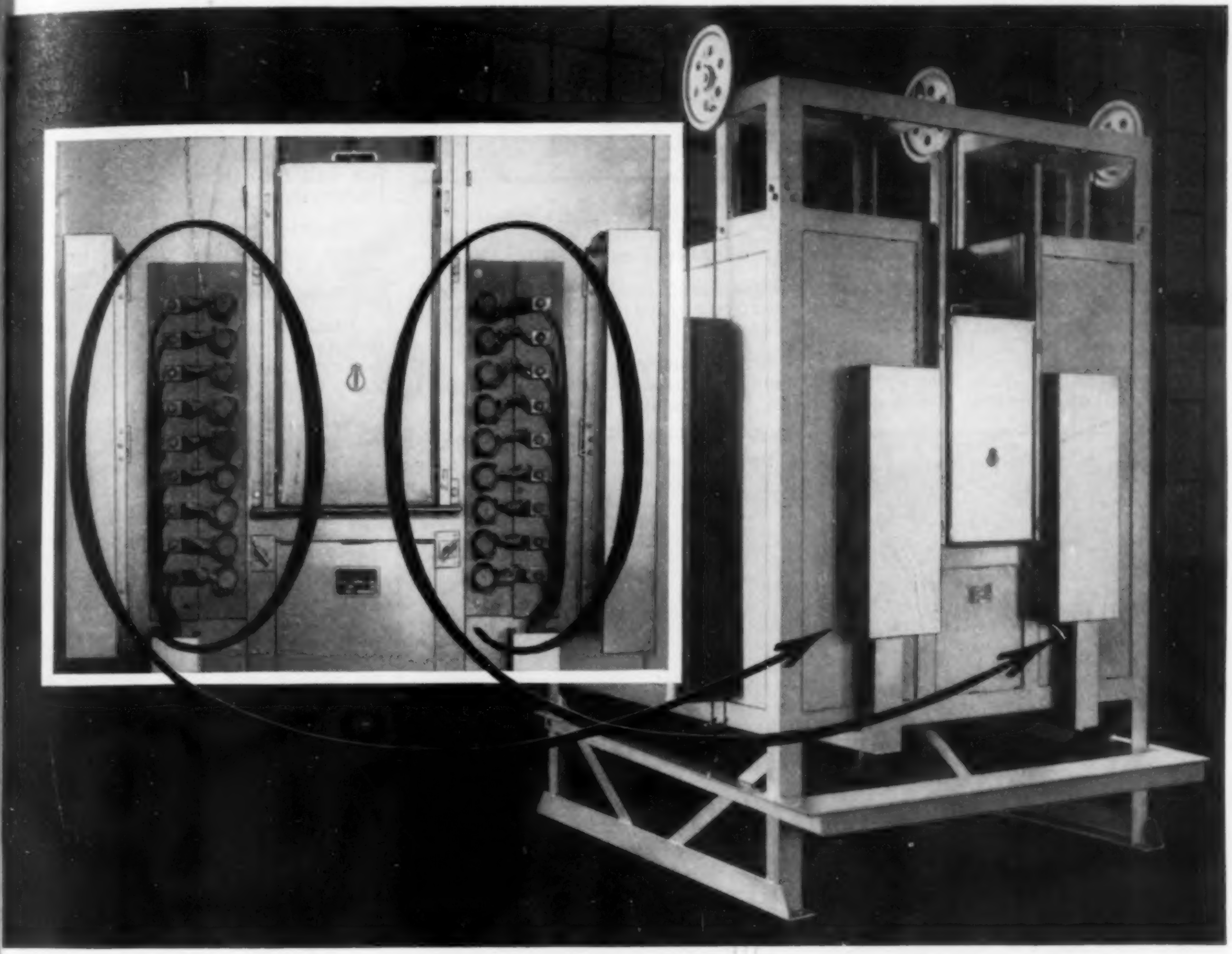
Airless Rotoblast. Pangborn Corp. Bulletin 176.

Cadmium Plating. E. I. duPont deNemours & Co., Inc. Bulletin 177.

Rust inhibiting wax coatings for protection of metal. S. C. Johnson & Son, Inc. Bulletin 180.

Tumbling and cleaning. Globe Stamping and Machine Co. Bulletin 179.

Use Handy Coupon on Page 544 for Ordering Helpful Literature. Other Manufacturers' Literature Listed on Pages 544, 546, 548, 550, 554, 556, 558, 560, 562, 566, 568, 572 and 574.



WHAT'S NEW

IN MANUFACTURERS' LITERATURE

Catalog on finishing and cleaning. Frederick Gumm Chemical Co., Inc. Bulletin 292.

Resilon corrosion-resistant tank linings and applications are described in 8-page leaflet by United States Stoneware Co. Bulletin 291.

"Indium and Indium Plating". Indium Corp. of America. Bulletin 182.

Jetal process and its characteristics as a protective coating. Alrose Chemical Co. Bulletin 213.

Illustrated booklet describes blast cleaning equipment offered by Ruemelin Mfg. Co. Bulletin 360.

Lead plating is discussed in new booklet issued by Harshaw Chemical Co. Bulletin 109.

Discussion of anodizing, chromatizing and phosphatizing in illustrated 60-page book has been issued by Turco Products, Inc. Bulletin 243.

Service report describes use of Oakite machining, drawing, degreasing and descaling materials. Oakite Products, Inc. Bulletin 210.

Tumbl-Spray metal washing machine is described in new leaflet issued by American Foundry Equipment Co. Bulletin 413.

Modern polishing wheel weight to give a polishing wheel perfect balance are described by the Manderscheid Co. in Bulletin 417.

Metal cleaning solutions for various metals are described in leaflet issued by the DuBois Co. Bulletin 419.

Three new booklets have been issued by the Enthone Co. describing an acid addition agent, hard drying rust-inhibiting waxes and a new alkali steel cleaner. Bulletin 420.

Special data sheets on compounds for various cleaning jobs are offered by MacDermid, Inc. Bulletin 436.

Technical bulletin describes materials developed to meet specialized processing and cleaning needs. Kelite Products, Inc. Bulletin 438.

New 1944 catalog describes metal cleaning equipment offered by N. Ransohoff, Inc. Bulletin 439.

Several practical data sheets show cleaning methods used on aluminum, brass and steel. Diversey Corp. Bulletin 446.

New 144-page catalog "Chemicals by Glyco" features many tables of useful chemical and physical data. Glyco Products Co., Inc. Bulletin 449.

Technical Service data sheets on pickling solutions. American Chemical Paint Co. Bulletin 456.

ENGINEERING • APPLICATIONS • PARTS

New 32-page illustrated booklet contains much data on manganese steel for the railroad industry. American Manganese Steel Div. Bulletin 388.

Illustrated leaflet presents data and uses of special alloys resisting corrosion, high temperatures and abrasion. The Duraloy Co. Bulletin 390.

Catalog gives complete specification data on Bunting bearings and bars. Bunting Brass & Bronze Co. Bulletin 343.

Heat treating fixtures for pit-type furnaces are shown in new booklet by Driver-Harris Co. Bulletin 363.

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WHAT'S NEW

IN MANUFACTURERS' LITERATUR

Pressed steel pots are described b Bell & Gossett Co. in new Bulleti 364.

Carburizing Boxes. Pressed Ste Co. Bulletin 193.

54-page booklet, "File 41—Eng neering Data Sheets", gives comple facts on Ampco Metal's physic properties and service record. Bu letin 368.

New information sheets on tapere and formed tubes have just bee issued by Summerill Tubing Co. Bu letin 369.

Chace manganese alloy No. 772 i sheets, strips, rod and special shap described by W. M. Chace Co. Bu letin 190.

Electrical, corrosion and heat r sisting alloys in rod, wire, ribbo and strip forms. Wilbur B. Driv Co. Bulletin 192.

Meehanite Castings. Meehanite R search Institute. Bulletin 196.

X-Ray Inspected Castings. Elect Alloys Co. Bulletin 197.

Steel Castings. Chicago Steel Fou dry Co. Bulletin 199.

Heat Resisting Alloys. General A loys Co. Bulletin 200.

Pipes and Tubes. Michigan Ste Casting Co. Bulletin 201.

Bimetals and Electrical Contac H. A. Wilson Company. Bulletin 20

Cr-Ni-Mo Steels. A. Finkl & So Co. Bulletin 203.

Industrial baskets, crates, trays an fixtures. Rolock, Inc. Bulletin 204

Cooper standard alloys. Coope Alloy Foundry Co. Bulletin 206.

Many applications and savin through use of drop forgings a shown in Drop Forging Topic issued by Drop Forging Assn. Bu letin 240.

24-page catalog is guide to prope ties and use of Monsanto plasti Monsanto Chemical Co. Bulletin 31

Alloy Castings. Ohio Steel Found Co. Bulletin 207.

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At present, Rockrite tubing is being used, to the limit of our capacity, for products needed for victory. However, we will be glad to furnish such information as may be desired by designers and production executives who are interested in the cost of post-war products in which Rockrite tubing may be used.

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WHAT'S NEW

IN MANUFACTURERS' LITERATU

Details of new Chemicast proc for small brass parts will be suppli by Chemicast Div., Whip-Mix Co Bulletin 330.

Reference data book entitled "' Improvement of Metals by Forgi has been issued by Steel Impro ment & Forge Co. Bulletin 409.

16-page catalog illustrates w variety of welded steel crates a baskets for pickling, enameling a heat treating operations. Youn town Welding and Engineering (Bulletin 423.

Industrial applications of Nati al and Karbate carbon and graph products are illustrated in 16-pa booklet issued by Natonal Carb Co., Inc. Bulletin 426.

Illustrated leaflet describes sta less steel castings by Atlas Foun Co. Bulletin 437.

Many types of heat treating a pickling baskets and containers shown in new booklet by the St wood Corp. Bulletin 445.

Complete line of Mallory rad electrical and electronic parts, w sizes, dimensions and rated cap ities is described in new 36-p booklet. P. R. Mallory & Co., I Bulletin 448.

Interesting and informative lite ture on "Pomet" powder me lur products. Powder Metallurgy Co Bulletin 454.

Specifications and physical pr erties of bronze and aluminum all are shown in Olds Alloys Co. Bu tin 457.

Three-color chart of decimal equ alents. John Hassall, Inc. Bulle 458.

MELTING • CASTING • MI OPERATIONS

52-page booklet describes Mo rapid Lectromelt furnaces for ir steel, nickel and copper melting a refining. Pittsburgh Lectromelt F nace Corp. Bulletin 404.

Use Handy Coupon on Page 544 for Ordering Helpful Literature.
Other Manufacturers' Literature Listed on Pages 544, 546, 548, 550, 55 556, 558, 560, 562, 564, 566, 568 and 57

Mocking birds don't mate with meadow larks . . . nor do robins and barnyard ducks lay eggs in the same nest. Birds of a feather just naturally flock together . . . keeping each species separate, distinctive, true to type.

It's the same way with Welding Electrodes.

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WHAT'S NEW
IN MANUFACTURERS' LITERATUR

Cradle furnace which produces homogeneous gray iron of unifor chemical analysis, uniform temper ture and controlled carbon conte is described by Whiting Corp. Bu letin 357.

"Electromet Products and Service Electro Metallurgical Co. Bullet 186.

Interesting and helpful inform tion available on the use of all pots for heating operation by t Swedish Crucible Steel Co. Bullet 137.

Crucibles for brass, copper, alum num and magnesium industrie Electro Refractories and Alloys Cor Bulletin 183.

Ingot Production. Gathmann Eng neering Co. Bulletin 185.

Manganese-Titanium Steels. Tit nium Alloy Mfg. Co. Bulletin 184.

Electric Furnaces. Detroit Electr Furnace Div., Kuhlman Electric C Bulletin 189.

Operating Features, capacitie charging methods of the Herou electric furnace. American Brid Co. Bulletin 215.

Coke oven plant construction an development in 1942 is describ and illustrated in 12-page pamphl by the Koppers Co. Bulletin 232.

"Fisher Magnesium Scrapbool Fisher Furnace Co. Bulletin 281.

Attractive booklet describ growth, facilities and offers valual alloy hints. Niagara Falls Smelti & Refining Corp. Bulletin 246.

Vertical centrifugal casting m chine for production of ferrous an nonferrous castings is described b Centrifugal Casting Machine Co. Bulletin 315.

Interesting, descriptive leaflet metal reclaiming mill offered Dreisbach Engineering Corp. Bul tin 284.

GENERAL

New leaflet describes interoffi communication system offered Executone Communication System Bulletin 385.

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